The Epidemiology and Spatial Trends of Tuberculosis in South Africa, 2005–2015: Evidence from the Electronic TB Register, the Civil Registration System, and Policy Guidelines

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Abstract

Background: Tuberculosis (TB) can be prevented through vaccination with the Bacillus Calmette-Guerin (BCG) vaccine, but it still poses a major global health problem. South Africa, with an estimated annual TB incidence of 301,000 cases in 2018, remains one of the most TB burden countries. Current estimates show that the eight most burden TB countries—India (leading), China, Indonesia, the Philippines, Pakistan, Nigeria, Bangladesh, and South Africa—account for two thirds of the total TB burden.

The 2018 figures for South Africa translate into an increase of 400% over the preceding 15 years. Furthermore, South Africa still falls below its targets of a case detection rate of at least 70% and successful treatment of 85% among new smear positive cases initiated on treatment. Monitoring and measuring progress in achieving these targets requires robust and high quality TB surveillance systems. In this way, policies and intervention programmes regarding the TB burden in South Africa will be derived using accurate TB data. It was in this context that the current research was set to contribute by:

- Exploring the extent of the completeness of TB surveillance systems in South Africa;
- Describing and modelling spatial epidemiology of TB;
- Investigating the impact of Antiretroviral Treatment (ART) on TB notifications and mortality; and
- Reviewing the quality of TB, the Human Immunodeficiency Virus (HIV), and ART policy guidelines in South Africa.

Method: This research is a quantitative dominant mixed methods study which used secondary TB surveillance data which is routinely collected by the Department of Health, and TB mortality data (for the period 2005-2015) that is collated by Statistics South Africa. The TB data sets were the Electronic TB Register (ETR), n= 3,474,320 and the Civil registration system, n= 776, 176. In addition, 14 South African TB and HIV/ART policy guidelines for the period 2004-2016 were reviewed.

An evaluation of the TB surveillance system was done using the updated Centres for Disease Control (CDC) guidelines on how to evaluate a surveillance system and then an epidemiological analysis of the two TB data sets was conducted. This was followed by the geospatial analysis of both data sets using the Global and Local Moran's Indices to identify spatial autocorrelation and clustering respectively, the Local G to identify hot spots, and Spatial Lag Regression to identify spatial dependency. Further analysis was performed for the

concordance between ART and TB. Finally, TB and HIV/ART policy guidelines were analysed using the Appraisal of Guidelines for Research and Evaluation (AGREE) II tool.

Results: Evaluation of the TB system revealed that variables in the ETR data for date of birth, HIV status, and ART had low levels of completeness (5.1-62.1%, 20.6-90.6%, and 0.01-19.7% respectively) for the period under study. Furthermore, only two variables for the TB data from the civil registration system—smoking status and level of education of the deceased—had low levels of completeness. Other findings were a delay in initiating TB treatment in Western Cape province. Furthermore, the study revealed that the total number of TB deaths recorded in the ETR were not the same as those in the civil registration system; in fact, the ETR identified approximately 39% of the total TB deaths in the civil registration system.

The epidemiological analysis of the mortality TB data in South Africa for the period 2005-2015 showed a significant decrease in the cumulative annual TB death rate. Furthermore, TB affected more males than females, with more deaths in the 35-44 age group for both males and females.

The geospatial results revealed that some district municipalities had higher TB notification and death rates than others. The study further identified a positive association between TB notification and death rates, and the South African Multidimension Poverty Index (SAMPI) and HIV. Other findings were a spatial autocorrelation in the TB notification and death data for 2005 and 2010. Furthermore, this study demonstrated a presence of hot spots for the overall, male and female crude and age sex standardised TB notification and death rates in 2005 on the north western part and in 2010 in the eastern region of South Africa.

Results of the concordance between ART and TB showed a decrease in the TB case notification and TB death rates that may be attributed to ART uptake.

The AGREE II results showed that in all the reviewed TB and HIV/ART policy guidelines, the 'Clarity of presentation' domain had the highest scores; however, none of the reviewed policy guidelines could be recommended for use, therefore requiring improvement. Results for the extracted recommendations for data management, monitoring, and evaluation revealed that 50% (seven) of the policy guidelines did not have any recommendations that could be associated with data management, monitoring, and evaluation. Those that did, recommended accurate data recording, data collation, and analysis by the different levels in the health system (health facility, sub district, district municipality, province and national).

Conclusion: This study has demonstrated that there are data quality issues for the South African TB surveillance system, particularly the completeness of some variables and the timeliness. Furthermore, the study identified TB hot spots in certain parts of the country. In addition, the study confirmed the utility of the Geographic Information System (GIS) to demonstrate any presence of areas with high risk of TB. It has further demonstrated that the quality of the reviewed TB and HIV/ART policy guidelines was poor. This information is useful for the South African TB programme.

Furthermore, the findings indicated a disproportionate distribution of the TB burden which means that certain groups of people in South Africa (e.g., males and those in the 35-44 age group), including those living in locations with high levels of SAMPI and HIV, had a higher burden of TB during the period of study. The existence of these identified inequalities in the burden of TB underscores the importance of developing targeted public health interventions and policies to be directed towards the most vulnerable populations who happen to be those with observed high TB notification and death rates and are located in district municipalities with hot spots.

As mentioned earlier, this research identified gaps in the TB surveillance data. Gaps in the surveillance TB data have major implications for TB surveillance; for example, if the TB mortality data have more deaths than the TB surveillance data, as was the case for this study, this means that there is a possibility that a number of people infected with TB were never identified by the surveillance system. Furthermore, it may imply that there is an under reporting of TB notifications which may have ramifications in terms of continued undetected TB infections in the community.

TB can be prevented and cured, but it can be argued that the continued existence of poor TB data may, in part, contribute to the factors that have sustained TB to remain a challenge for South Africa. Addressing the identified challenges facing TB surveillance in South Africa will require engaging with the vulnerable groups right from the time when policies are being developed, as suggested in the AGREE 11 tool attribute of stakeholder involvement, followed by directing enough resources into TB prevention activities and surveillance data management at a district municipal level.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any degree or diploma of a university or other institution of higher learning.

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Dan Kirwana Kibuuka

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Ethics Approval

The study was approved by the Auckland University of Technology Ethics Committee (AUTEC) in New Zealand, reference number **17/369** dated 17th December 2017 (Appendix A, p. 294). The study further received approval from the human research ethics committee of the South African Medical Research Council, reference number **EC006-5/2018** dated 22nd August 2018 (Appendix A, pp. 295-296).

Chapter One - Introduction

1.0 Introduction

This chapter begins by introducing the researcher and providing the reasons that led to the researcher carrying out the current study. An overview of South Africa will be provided focusing on information that is relevant for this study. The researcher will then briefly discuss the burden of tuberculosis (TB) globally and in South Africa. Next, the socio-economic and political contexts in South Africa will be discussed because of their importance in understanding their role in the distribution and impact on the burden of TB in the country. Furthermore, lack of access to health services is considered because it is of importance in South Africa.

The chapter then provides background information about public health surveillance systems and what has been done in South Africa regarding the evaluation of TB surveillance systems. Geospatial analysis is then introduced, followed by a brief introduction to Antiretroviral Treatment (ART). Furthermore, this chapter introduces the topic of the evaluation of policy guidelines. This is important because effective policy impacts on the incidence and prevalence of TB. The rationale and significance of the study are also discussed in the chapter. The research question, hypotheses, study objectives, and the various research steps are outlined. The chapter ends with an overview of the organisation of the thesis.

1.1 A brief introduction about the researcher

The researcher joined the PhD journey after several years working in the health sector in South Africa. He trained as a veterinarian and did a Master's degree in epidemiology. Upon completion, the researcher joined the National Department of Health of South Africa in the Expanded Programme on Immunisation. During the researcher's employment at the Department of Health, he worked mainly with health data.

The researcher later joined Statistics South Africa, the organisation mandated to produce official statistics in South Africa. The researcher produced health reports using the health data that were collected by Statistics South Africa. During this time, the researcher had continuous interactions with colleagues at the National Department of Health because the work the researcher was doing somehow cross-cut with their work. The researcher was part of the task force team that was mandated to work on the first TB prevalence survey for South Africa. At the same time, the researcher was working on the South Africa Demographic and Health Survey. The researcher then realised that he had access to a lot of health data in his position.

This set the researcher thinking whether he should do research while using some of the data at his disposal. Because the burden of TB and the Human Immunodeficiency Virus (HIV) is so high in South Africa, this directed the researcher's thoughts to these two diseases. The researcher also realised that to do research, there was a need to empower himself through doctoral training.

1.2 Background

In this section an overview of South Africa is presented. The purpose of this background is to provide information on the geographical location of South Africa and selected health indicators.

1.2.1 An overview of South Africa

South Africa is the southernmost country on the African continent with a total surface area spanning more than 1.2 million km^2 and a total population of more than 57 million people; with 49% (28.2 million) males and 51% (29.5 million) females (South African Government, 2019; Statistics South Africa, 2019). Most of the population is composed of the black African ethnicity at 81% (47.4 million) of the total South African population. Black Africans are the indigenous population of South Africa; they are in the majority and most of them are of a lower socio-economic status (SES). Another group identified are known as Coloured and comprise 5.2 million. The White population is the third largest, estimated at 4.7 million; and the Indian/Asian population is the least of the four largest ethnicities at 1.5 million (Statistics South Africa, 2019).

South Africa borders with Namibia and Botswana on the northwest, Zimbabwe to the north, Mozambique to the northeast, and Swaziland to the east. Lesotho is surrounded by South Africa as seen in Figure 1.1 (see p. 4). South Africa is divided into nine provinces; namely Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West, and Western Cape (South African Government, 2019). The provinces are further divided into 44 district municipalities and 8 metropolitan municipalities; namely the City of Johannesburg, the City of Tshwane (includes Pretoria the capital city), Ekurhuleni to the east of Johannesburg, the City of Cape Town, eThekwini (includes Durban), Nelson Mandela Bay (includes Port Elizabeth), Buffalo City, comprising greater East London and Mangaung, comprising greater Bloemfontein (Brand South Africa, 2010). Gauteng province has the largest population with more than 15 million people; whereas Northern Cape province has the least population of 1.2 million people (Statistics South Africa, 2019). South Africa has 11

official languages. With the exception of English and Afrikaans, the other nine languages are mainly based on the provinces for instance isiXhosa and Setswana are predominantly spoken in Eastern Cape and North West respectively (South African Government, 2019).

In 2019, the life expectancy at birth for South Africa was 61.5 and 67.7 years for males and females, respectively. Low life expectancy may be due in part to the effects of HIV where an estimated 7.97 million people were living with HIV and the prevalence rate was estimated at 13.5% in 2018 (Statistics South Africa, 2019). Moreover, HIV mainly affects those aged 15-49 years, with an estimated 19.07% of   the total population being HIV positive in 2019. In addition to a low life expectancy at birth, South Africa has a high infant mortality rate which was estimated to be 22.1 per 1 000 live births in 2019 (Statistics South Africa, 2019). The observed high levels of infant mortality are mainly due to the impact of HIV (Sartorius, Kahn, Vounatsou, Collinson, & Tollman, 2010; Schatz & Ogunmefun, 2007). Furthermore, South Africa, with a generalised HIV epidemic (Human Sciences Research Council, 2014), has the highest number of HIV co-infected TB cases globally (Churchyard et al., 2014; Williams et al., 2015)—estimated to be 6.3 million people in 2013 (Williams et al., 2015). In 2012, an estimated 65% of   patients with TB in South Africa were known to be co-infected with HIV. Moreover, in South Africa death rates amongst co-infected patients are high. In 2015, mortality rates in South Africa for those infected with only TB was estimated to be 46 per 100 000 and for those co-infected with HIV was 133 per 100 000 (World Health Organization [WHO], 2016a).

Figure 1.1: *Map of South Africa with Provinces and Neighbouring Countries*

Source: South Africa maps (The University of Texas at Austin, 2019).

1.3 Brief introduction to TB

Tuberculosis poses a major health challenge globally (WHO, 2017) despite the fact that early diagnosis and correct treatment can cure those who are infected, in addition to availability of prophylactic treatment and the Bacillus Calmette-Guerin (BCG) vaccine (Heemskerk, Caws, Marais, & Farrar, 2015). There is currently no continent that is not affected by the scourge of TB, although the burden varies between countries as well as within countries themselves (Lönnroth, Jaramillo, Williams, Dye, & Raviglione, 2009; WHO, 2019). Annually, the number of TB prevalent cases is approximately 10 million people globally (WHO, 2017) with more than one million deaths (Global Burden of Disease Tuberculosis Collaborators, 2018). Most of these deaths are in developing countries.

It is estimated that there is a new infection with the TB bacterium every second globally (Butler & Carr, 2013). By 2020, researchers have indicated that there will be one billion people infected with TB throughout the world and over 150 million of those infected will develop symptomatic TB, leading to an estimated total of 36 million deaths (Butler & Carr, 2013). For almost a decade, TB has caused more deaths than the HIV/Acquired Immunodeficiency Syndrome (HIV/AIDS), making it the single leading cause of death from an infectious disease (WHO, 2017).

1.4 Current burden of TB in South Africa

Recent data show that South Africa remains one of the eight countries with the highest burden of TB disease in the world. South Africa's TB burden follows those of India, China, Indonesia, the Philippines, Pakistan, Nigeria, and Bangladesh; with an estimated annual incidence in South Africa of 301 000 cases of active TB in 2018, an increase of 400% over the last 15 years (WHO, 2019) mainly attributed to the HIV epidemic.

South Africa is faced with a TB epidemic that is mainly as a result of the HIV infection (Churchyard et al., 2014). The HIV infection is known to alter the clinical manifestation of TB with a resultant rapid progression to active disease (DeRiemer, Kawamura, Hopewell, & Daley, 2007; Venter, 2018), due to the immunosuppressive effect of HIV. Immunosuppression occurs as a result of the depletion of the cluster of differentiation 4 (CD4$^+$T) cells that are responsible for protecting the body against infection (Bruchfeld, Correia-Neves, & Källenius, 2015; Pawlowski, Jansson, Sköld, Rottenberg, & Källenius, 2012). Those who are immunosuppressed are more susceptible to TB.

Contrary to other high TB burden countries (defined as the 20 countries with the highest absolute number of TB cases and an additional top 10 countries with the most severe burden of TB per population), the South African TB epidemic is characterised by both the highest estimated incidence and prevalence of TB cases (Churchyard et al., 2014).

1.5 Socio-political context of South Africa and its impact on TB

It has been over 20 years since South Africa underwent a peaceful transition from minority white rule to a constitutional democracy. However, the health and well-being of most South Africans remain afflicted by a persistent burden of a number of infectious diseases; for example, TB. In addition to infectious diseases, non communicable diseases and social disparities also persist (Benatar, 2013; Mayosi & Benatar, 2014).

In South Africa, the existence of poverty, inequality in SES and disparity in accessing basic social services (see section 1.6 on lack of access to health services) between population groups, provinces, and socioeconomic groups are distinctive and substantial. Therefore, it may be argued that all of these have led to inequalities in health. This is supported by Ataguba et al. (2011) who indicated that the poor face many predisposing factors to TB (see section 2.8 for risk factors) and may not be able to seek care when they are sick due to various reasons related to affordability (Ataguba, Akazili, & McIntyre, 2011). This study will be investigating the epidemiology of TB which is an infectious disease and confirm the already established association between TB and SES.

1.6 Lack of access to health services

South Africans had hoped for a better quality of life after the end of the white minority rule, but disparities have continued (Mayosi & Benatar, 2014). Although many South Africans, with the inclusion of even those in positions of power, have been introduced to living generous and extravagant lifestyles, wasteful consumption patterns, and favouritism—all of which frustrate the spirit required to reduce inequities (Mayosi & Benatar, 2014)—most South Africans remain severely impoverished (Benatar, 2013). Since achieving democracy in 1994, the South African Government has tried to address inequities but there is substantial evidence to suggest that these still exist in accessing and utilising of health care services among socioeconomic groups (Benatar, 2013; Coovadia, Jewkes, Barron, Sanders, & McIntyre, 2009; Gilson & McIntyre, 2007).

There is a large proportion of South Africans who are affected by extreme poverty. This has affected their health predominantly due to an inability to access the basic requirements of life;

for instance, sufficient nutrition, adequate sanitation and appropriate housing conditions (Benatar, 2013; Mayosi & Benatar, 2014). Household crowding, usually as a result of poverty, has been related to diseases of the respiratory system like TB (Quinn & Kumar, 2014). In addition, direct links between access to healthcare and psychological stress have been demonstrated to be highest among those in the low-income category and this may result in impairing the functioning of the immune system, leading to an increase in susceptibility to disease (Quinn & Kumar, 2014; Wilkinson & Pickett, 2011). According to Ataguba and colleagues (2011), a high burden of diseases and disability is mostly observed in those populations that are in the lower SES in South Africa. In addition, non communicable diseases, that are usually seen as health conditions of affluence, are commonly being reported in people of lower SES (Ataguba et al., 2011). Furthermore, according to Navarro (2002), inequalities as a result of an increase in wage disparity have led to a slowdown in the improvement of health and a decline in the levels of health in developing countries because those on low wages may not be able to access health services (e.g., TB care).

1.7 Background on public health surveillance systems

This research investigates the current TB surveillance systems in South Africa; therefore, it is important that background information is provided so that the reader can differentiate the different types of surveillance. Furthermore, it is important to highlight this early in the thesis so that the reader can understand the importance of TB surveillance. Public health surveillance is defined as the routine collection of data which are analysed, interpreted, and disseminated for the purpose of public health action (Porta, 2008). Public health surveillance systems play an important role in establishing occurrence of a disease in a population. Establishing disease occurrence is an important step that may lead to the implementation of interventions in order to halt further transmission of the disease. As a result, public health surveillance systems play a critical role in the reduction of the impact of morbidity and mortality in the population due to the disease that is under surveillance (Garcia-Abreu, Halperin, & Danel, 2002). Moreover, the purpose of public health surveillance systems is to enable the assessment of the health status and trends of disease in a population, guide the allocation of resources, assess how effective the disease prevention programme is, and identify if there is a need for research to be conducted (B. C. K. Choi, 2012).

The key actions that enable the surveillance system to achieve its purpose are the collection of data, followed by its analysis and processing. These surveillance data may be collected from a number of sources; for example, from clinical or laboratory diagnosis and death

notifications (WHO, 2000). Therefore, for this study, the surveillance data that are used are derived from the Electronic TB register (ETR) and the death notifications in the civil registration (CR) system. Furthermore, the data that are generated by the surveillance system may also be used for planning, monitoring, and evaluation of public health activities, determining the geographic distribution and trend of the disease with the ability to detect an outbreak (B. C. K. Choi, 2012). However, to facilitate better planning of public health activities, it is important that the surveillance data are of good quality (Amato-Gauci & Ammon, 2008; Podewils et al., 2015). This study will be evaluating the data quality of the South African TB surveillance system.

1.8 Types of surveillance

Surveillance systems may be used either for rapid response as is the case for the Corona Virus Disease-19 (COVID-19) or planned longer term response. South Africa, like most countries, has a list of notifiable diseases (e.g., TB and measles) that are under different types of surveillance (e.g., passive or active) and so require mandatory reporting (Department of Health, 1999). The different types of surveillance use different types of routinely collected information and it is the accumulation of this information which allows the estimation of the incidence of a disease with accuracy.

In general, surveillance activities are classified in three categories: passive, active, and sentinel surveillance. In the next section, the researcher will focus on passive surveillance because it is the one that is applied when undertaking TB surveillance. Sentinel surveillance is defined as the monitoring of specific diseases in a sample of a population in order to establish health trends in that population through regular standardised reports (Bonita, Beaglehole, & Kjellstrom, 2006).

1.8.1 Passive surveillance

Passive surveillance is when either health facilities or laboratories that are part of a hierarchical reporting network regularly report occurrence of disease. There is no active search for cases, patients normally present themselves to the health facilities (WHO, 2018b). Similarly, in South Africa, TB patients present themselves to a health facility and, if they are suspected to have TB, samples are taken from them for processing at laboratories. Data are captured at the health facility, as well as at the laboratory, reports are then generated and sent to the next level (WHO, 2018b). Passive surveillance activities are usually reported either weekly or monthly, this enables the capturing of trends and specific disease indicators of the patient; for example, age, sex or gender and ethnicity (WHO, 2006a). Because

surveillance involves different organisations, in order to perform passive surveillance, there should be cooperation between all the organisations that are involved in the surveillance system. These organisations are: laboratories, hospitals, health facilities, and private health practitioners. The cooperation is important so that occurrence of the disease can be reported to the next level of administration (WHO, 2018b).

The main purpose of passive surveillance (also known as routine surveillance), is to assess and monitor disease trends (Losos, 1996). Passive surveillance plays a critical role in establishing the burden of disease; however, it can under estimate the true burden of disease due to poor diagnosis, especially where there is lack of confirmatory diagnosis by a laboratory (WHO, 2006a).

Although passive surveillance is relatively inexpensive and requires fewer resources, it has weaknesses in that it might be difficult to obtain complete and accurate data. This may be as a result of many cases not being reported to health facilities and incorrect diagnosis of cases by primary health care workers (WHO, 2006a). Because of weaknesses of passive surveillance, interpretation of the data it produces should be done with caution (C. J. L. Murray, Lopez, & Wibulpolprasert, 2004; WHO, 2006a).

1.9 TB surveillance systems

Surveillance has been identified as a critical part of TB control (Bourgeois, Zulz, Soborg, & Koch, 2016). A TB surveillance system produces TB data that are essential for planning, intervention, monitoring trends, and policy decision making of the national TB programme. South Africa provides information that is used to monitor international goals; therefore, the TB data from the surveillance system are critical for monitoring the United Nations Sustainable Development Goals (SDGs) which were launched in 2015. The TB data will inform South Africa whether it is on the path of achieving the reduction of TB incidence by 80% and mortality by 90% as compared to their 2015 baseline by 2030 (Sprinson, Lawton, Porco, Flood, & Westenhouse, 2006).

Tuberculosis surveillance in South Africa is conducted through the ETR, which was implemented in 2005 (Podewils et al., 2015), and the laboratory. Surveillance begins when TB data are captured on what is termed the patient TB Blue card (see Appendix B) at the health facility, from which it is collated into a paper form TB register. From the paper form TB register at the health facility, the TB data are then entered into the ETR at the sub district level (Mlotshwa, Smit, Williams, Reddy, & Medina-Marino,

2017; Podewils et al., 2015). This is then further collated at the next levels (i.e., district, province, and national). Failure to collate data at all levels is likely to impact on the TB data quality in South Africa. Therefore, this research investigates the TB data quality that is collected by the South African TB surveillance system.

1.10 Evaluation of the TB surveillance system in South Africa

The Centres for Disease Control (CDC, 2001) recommends that in order for a surveillance system to generate accurate data, the system should be regularly evaluated; the WHO also had a similar recommendation for South Africa in 2009 (Podewils et al., 2015). Despite these recommendations, South Africa has conducted only two TB surveillance system evaluations to date. Moreover, these two evaluations were not done at a national level which means that the results cannot be generalised. In 2011, an evaluation of the TB surveillance system was done in the Cape Metro region of Western Cape Province using the 'Updated Guidelines for Evaluating Public Health Surveillance Systems' of the Centres for Disease Control and Prevention. Findings of the evaluation were that the Cape Metro's TB surveillance was strong, although software flexibility and availability of TB-HIV co-infection and MDR-TB data needed improvement (Heidebrecht, Tugwell, Wells, & Engel, 2011).

Contrary to the Cape Metro findings, the second evaluation in three provinces, conducted by Podewils and colleagues in 2011, found that there was a need to address completeness and reliability of the TB data in South Africa; although they did not use the 'Updated Guidelines for Evaluating Public Health Surveillance Systems' (Podewils et al., 2015). This evaluation demonstrated that one-third of individuals diagnosed with TB disease might not have been informed of their disease or started on treatment because the ETR did not capture all the TB patients. Furthermore, among patients that were confirmed or suspected to have TB, completeness and reliability of information in the TB surveillance system was not consistent across data sets; that is, the TB Blue Cards, the paper TB register and the ETR (Podewils et al., 2015).

This study is the first TB surveillance study in South Africa that evaluated the TB surveillance system utilising two national level TB data sets (see research methods chapter) that are managed by two different South African Government Departments at a national level and are governed independently of each other. In addition to examining the data quality of the South African TB surveillance system, this study will provide insight into the completeness, timeliness, and concordance of the surveillance system. These attributes (completeness and

concordance) were not previously investigated at a national level, and timeliness has never been investigated, even at a lower level.

Evaluation of a surveillance system is critical in making sure that disease trends can be monitored effectively by an adequately functioning surveillance system. This is especially true during the current COVID-19 pandemic which requires considerably strengthened surveillance systems that have the capability for the rapid identification of COVID-19 cases, then contact trace and quarantine others with whom they have been in contact (WHO, 2020a). In fact, the WHO (2020a) recommended that surveillance for COVID-19 requires that the existing national surveillance systems be adapted and reinforced.

1.11 Introduction to geospatial analysis

Estimating the presence of TB clusters (hot spots) has been mainly done using the Geographic Information System (GIS) (Shaweno et al., 2018). Although, the use of geospatial analysis to provide the much needed information for purposes of planning for TB services has been described in middle income countries, it has mainly been conducted in high income countries (Porter, 1999). Policies to prevent and manage diseases (e.g., TB) require knowledge of the location and an understanding of the people that are at risk, their communities, and surroundings (Bagheri et al., 2015). Geospatial statistics can be utilised to provide this information. Therefore, to understand TB dynamics, this PhD study will conduct a geospatial analysis of TB notification and death rates for the period 2005 and 2010 in South Africa. This will be for the first time that the presence of TB hot spots for both TB notifications and deaths at a district municipality level is investigated in South Africa. This is critical information that may be used by the Government when formulating policies. Establishing the existence of TB hot spots is key to identifying those vulnerable populations that may need targeted TB interventions.

1.12 A brief introduction to ART

As stated earlier, South Africa is faced with a TB epidemic that is mainly as a result of HIV infection (Churchyard et al., 2014). It may be argued that providing ART to those that are co-infected, may have a big impact on the TB epidemic in South Africa. In 2004, South Africa started rolling out the ART programme. Therefore, this research investigates if there has been any impact of the implementation of ART to TB notifications, TB/HIV co-infections, and deaths.

1.13 Introduction to the review of policy guidelines

It has been argued that policy guidelines should provide recommendations that are evidence based so that they can benefit the target group to whom the policy guideline is meant to apply; for instance, patients that are affected by a particular health condition (Beckett et al., 2019; Kredo, Gerritsen, van Heerden, Conway, & Siegfried, 2012) such as TB. Those policy guidelines with evidence based support would have recommendations for interventions that would improve the outcomes of patient care (Beckett et al., 2019). Due to the increased use of policy guidelines by health professions, there has now been a shift towards paying particular attention to their quality. For policy guidelines to be beneficial to their target population they should be of good quality; this PhD is the first study that will review TB and HIV/ART policy guidelines for the period 2004-2016 in South Africa in order to assess their quality. Good quality policy guidelines are a crucial component of the TB programme because health professionals need clear and non ambiguous policy guidelines to follow so that TB patients can benefit from evidence based services. Furthermore, policy guidelines should provide recommendations on TB data management with an aim that those involved in TB surveillance data management can collect good quality data. In addition to reviewing the quality of the policy guidelines, this PhD will review the policy guidelines in order to establish if they are being followed, especially as regards to the recommendations for TB data management, monitoring, and evaluation.

1.14 Rationale and significance of the study

The WHO estimates TB incidence for countries including South Africa; however, these estimates may not be reliable since estimating annual TB incidence is a challenge, especially in a high TB burden country like South Africa where cases may be missed by the notification system which may result in an underestimate (Pandey, Chadha, Laxminarayan, & Arinaminpathy, 2017). Furthermore, poor quality TB data may lead to either over or under reporting resulting in unreliable TB data at a local or national level and an inability to understand the true epidemiology of TB. This means that the TB programme and policies will be relying on inaccurate TB data which may result in poor policies and a misdirected use of resources which will impact the epidemiology of TB. Tuberculosis policies are driven by the epidemiology, or should be, but currently there is uncertainty on how good the TB epidemiology is; hence this study. Furthermore, South Africa still falls below its targets of a case detection rate of at least 70% and 85% successful treatment among the new smear positive cases initiated on treatment. An ideal surveillance system could assist South Africa in achieving

these targets by providing accurate data that can be used to guide the TB programme. However, in South Africa, the surveillance of diseases is historically weak (J. Murray, Davies, & Rees, 2011), not withstanding efforts of the National Department of Health to set up a surveillance system for TB. That is why this current research is re-evaluating it. The study will perform an epidemiological analysis of trends as well as a geospatial analysis of TB in order to establish the TB distribution pattern by sex or gender, age, race or population group, location, SES and HIV. Findings may assist South Africa to assess whether the set TB targets will be achieved.

The aim of this research, therefore, is to investigate the epidemiology of TB and explore the extent of the weakness of TB surveillance in South Africa. It is expected that this PhD research will contribute to new knowledge; for instance, the geospatial epidemiology of TB in South Africa which will be valuable for controlling the TB epidemic. The results of this research will lead to the development of an improved TB surveillance system in South Africa. It is expected that the research will also provide information that could be used to guide TB and HIV policy, and policy guidelines in South Africa. This research will provide new knowledge about the impact of ART on TB related deaths in South Africa.

1.15 Research question

The aim of this research is to investigate: How well does the TB surveillance system perform in South Africa, and what is the impact on the reported epidemiology of TB?

1.16 Hypotheses:

i)   There is a lack of concordance between the two key surveillance databases;

ii)   There is geographical variation in TB notification and death rates across South Africa;

iii)   High ART uptake will have reduced TB related mortality;

iv)   South Africa's TB and HIV/ART policy guidelines are of poor quality.

1.17 Objectives:

i)   To use the updated CDC guidelines to evaluate the TB surveillance system;

ii)   Identify gaps and concordances between the TB surveillance and TB mortality data;

iii)   Use data to describe the epidemiology of TB at a district municipality level;

iv)   Use GIS for spatial epidemiology of TB;

v)   Investigate the impact of ART on TB notifications and mortality; and

vi)   Use the Appraisal of Guidelines for Research and Evaluation II (AGREE II) tool to review the quality and extract recommendations for data management, monitoring, and

evaluation for the South African TB and HIV/ART policy guidelines for the period 2004-2016.

1.18 Type of study

The research is a quantitative dominant mixed methods study where the researcher performed analysis on two TB data sets that are managed individually by two South African Government Departments. Furthermore, TB and HIV/ART policy guidelines were reviewed. The research encompassed several steps:

1) Evaluating the TB surveillance system (completeness, timeliness, and concordance) using the updated CDC guidelines.

2) Conducting a descriptive epidemiological analysis on TB cases and deaths including data from the national ART programme.

3) Incorporating TB data with GIS data in order to undertake a geospatial analysis for TB cases and deaths.

4) Conducting a policy document analysis to review the quality and extract recommendations for data management, monitoring, and evaluation of TB and HIV/ART policy guidelines for South Africa for the period 2004-2016.

1.19 Overview of the thesis

Chapter One set the stage for this thesis where the researcher provided a brief introduction of himself. The researcher then described why TB is a major public health challenge globally and in South Africa. In this chapter the researcher further highlighted the socio-political context of South Africa, and the lack of access to health services as having a major impact on the occurrence of TB. Furthermore, background information on public health surveillance systems was provided in order to highlight the important role they play in the control of TB. The TB surveillance system, its importance and its evaluation, was discussed. The researcher considered the rationale and significance of the study in order to make a case as to why this study was conducted; and the research question, hypothesis, and objectives were introduced. The researcher finally described the study as a quantitative dominant mixed methods study and the steps involved.

In Chapter Two, the researcher provides the reader with information about the search strategy that was used to search for the literature. This is followed by a brief description of the clinical manifestation of TB, and the natural history and history of TB are described. The literature is critically reviewed in order to provide an in depth understanding of the TB epidemiology

covering the global perspective, then the sub-Saharan and finally South African perspectives. The researcher describes the national TB programme for South Africa to provide the reader with information on how TB information flows and the challenges that the programme faces. The researcher discusses the methods in Chapter Three providing information about the epistemology with a detailed study design, detailing the data sources and data analysis methods. In this chapter the researcher justifies why it is possible to use secondary data for health research. The results of the study are presented in Chapter Four (Evaluation of the TB surveillance system and epidemiological analysis), Chapter Five (Geospatial analysis), Chapter Six (Concordance between ART and TB), Chapter Seven (Review of the TB and HIV/ART policy guidelines), and Chapter Eight (Discussion). Chapter Nine presents the conclusion and recommendations.

Chapter Two - Literature review

2.0 Introduction

The previous chapter gave the background and the rationale of the study. In Chapter Two, the strategy that was used to search for the relevant literature of what is already known for this research is discussed. The literature helped the researcher to understand the epidemiology of TB, provide information about the clinical manifestation of TB, and an understanding of the natural history as well as the history of TB. This discussion will also provide the reader with necessary information on what is currently known about TB. Furthermore, in this chapter the researcher will discuss the diagnosis and treatment of TB, followed by the epidemiology of TB at a global level, then in sub-Saharan African nations and finally in South Africa. The researcher will continue by discussing risk factors for TB; HIV and TB coinfection; history of HIV; HIV and TB programmes in South Africa, surveillance (mainly because it is part of epidemiology) and disease control systems; TB policies and strategies first globally, then in sub-Saharan Africa and in South Africa; the national TB control programme of South Africa; and the evaluation of surveillance systems. A chapter summary will be provided.

2.1 Literature search strategy

The strategy for this research review included searching the Medical Literature Analysis and Retrieval System Online (Medline) via the Elton B. Stephens Co. (EBSCO) and PubMed databases for TB. The EBSCO and PubMed searches were important because EBSCO has a number of databases with full text that can be accessed, whilst PubMed consists of many citations, some with full text from online journals and books. Inclusion criteria included only papers in the English language, TB in humans, and those published within 15 years of this study to ensure that contemporary evidence was the focus.

Search terms included: "Tuberculosis", "transmission", "epidemiology", "surveillance" and "South Africa" as subject headings or MeSH for Medline (using pre-assigned words to search for articles), as well as "tuberculosis," "risk factors," "evaluation", "surveillance systems", and "transmission" as text words (words chosen by the researcher to ensure the search was extensive). In addition, the researcher contacted the AUT librarian who assisted him with the literature search.

The literature search was conducted for a period of four years beginning 2016. Journals focusing specifically on TB such, as the *International Journal of Tuberculosis and Lung Disease*, and the *Bulletin of the World Health Organization* were also searched. These journals

were chosen because more recent and relevant TB literature would be found in them and because they are specific for TB publications.

In addition to the auto alerts for Medline and PubMed, the researcher also subscribed to Google Scholar and set up alerts for updates using the same terms as for the alerts for Medline and PubMed. This was to capture any articles inadvertently missed through the methods described above. The search yielded 295 articles. The researcher first read the abstracts and then read the whole article if it was relevant to the aims of the research.

2.2 Clinical manifestation of TB

In this section a brief description of the clinical manifestation of TB is provided to show the reader the impact it can have on an infected individual. Signs (normally identified by a medical profession) and symptoms (identified by the patient) of TB disease may not be recognisable until the disease is in an advanced stage. A person is suspected of TB disease if there are symptoms like a cough that has lasted for more than three weeks, fever or sweating especially in the night, weight loss, tiredness, blood in the sputum and chest pain (American Lung Association, 2020; Crofton, Horne, & Miller, 1999). Pulmonary TB infection manifests as a cough that produces sputum (productive) although it is dry initially. However, children infected with pulmonary TB do not normally produce sputum. Other TB symptoms may include localised wheezing and breathlessness (Crofton et al., 1999; Gough & Kaufman, 2011). In addition to the symptoms, the signs of TB infection in children may include keratoconjunctivitis (inflammation of the cornea and conjunctiva) and painful joints (Sant'Anna, March, Barreto, Pereira, & Schmidt, 2009).

2.3 Natural history of TB

Tuberculosis is an air-borne (via respiratory droplets) disease that is caused by infection with the bacillus *Mycobacterium tuberculosis*. It is mainly transmitted from person to person via inhalation of respiratory droplets; the other modes of transmission are infrequent and are of no epidemiologic significance in humans (P. Glaziou, Sismanidis, Floyd, & Raviglione, 2014). Tuberculosis can infect any part of the body but people with pulmonary TB, in comparison to extra pulmonary TB, can transmit the infection to others (Blumberg, 2005). Pulmonary TB is the most common form of TB (Jeong & Lee, 2008); in 2018, it accounted for 85% (5.9 million) of the 7.0 million new and relapse cases notified globally (WHO, 2019). If a person infected with active pulmonary TB does not receive treatment, that individual will infect on average between 10 and 15 people annually (Blumberg, 2005). This is particularly important for South

Africa if it is to reduce the number of TB cases it will have to improve on the TB successful treatment which was 77% in 2017 (WHO, 2019). A person is infected with active TB when the bacteria overwhelm the immune system, or the immune system fails, as in HIV infection. This makes the bacteria replicate, causing tissue destruction, leading to the person exhibiting signs and symptoms (Gough & Kaufman, 2011). This is the situation that is currently prevalent in South Africa because the TB epidemic is fuelled by HIV as explained under the section of the current burden of TB in South Africa. There are no definitive symptoms of TB (Sterling, Pham, & Chaisson, 2010), but an infected individual may exhibit symptoms as those outlined in the clinical manifestation of TB. Inadequately controlled organism replication results in acute TB infection, which may manifest in a variety of clinical presentations. Clinical manifestations of TB depend on the virulence and dose of the infecting mycobacterium and the immune status of the host and the organ(s) involved (Getahun, Harrington, O'Brien, & Nunn, 2007). However, in some individuals who are not immunocompromised, the body defence mechanisms kill the tubercle bacilli and they exhibit no symptoms (Jacqueline, 2007). Furthermore, in people who are not immunocompromised, the host response mechanism may contain the tubercle bacilli, slowing down both its growth and multiplication making it dormant without causing disease (Russell, 2006). Without treatment, about two thirds of people will die of this disease (Sterling et al., 2010). This may in part explain the 37 per 100 000 population of TB deaths that were recorded in South Africa in 2018 (WHO, 2019). The importance of treatment has been underscored by the impact of COVID-19 in South Africa and the rest of the world.

Approximately 95% of those infected have a latent infection as a result of inactivity of the tubercle bacilli due to an effective immune response (Maher, 2009). A person with a latent infection is one who is infected with TB but does not exhibit active TB disease (Hauck, Neese, & Panchal, 2009). Of those persons with latent TB infection, about 2-5% will progress to TB disease at some point in their life time (Selwyn et al., 1989; Sutherland, 1976; Vynnycky & Fine, 1997) mostly due to reactivation of the dormant tubercle bacilli acquired from primary infection or less frequently by reinfection.

2.4 History of TB

Tuberculosis is a disease which has affected humans for millennia. As far back as 460BC, Hippocrates identified phthisis (a Greek term for TB) as the most widespread disease of the time globally (Konomi, Lebwohl, Mowbray, Tattersall, & Zhang, 2002). In Egypt, skeletal abnormalities suggesting TB disease in Egyptian mummies has been documented for more than

5,000 years (Cave & Demonstrator, 1939; Daniel, 2006). Early archaeological evidence of TB disease is also well documented in Peruvian mummies in America (Daniel, 2000). Tuberculosis was also described in India over 3,300 years ago (Brown, 1941; Morse, 1967). During the 16th and 17th centuries, TB was prevalent globally, with Europe and North America experiencing a TB epidemic during the 18th and 19th centuries (Daniel, 2006). Many Europeans who had been infected during the epidemic that had taken place in Europe are believed to have introduced TB into South Africa in the 17th century (Packard, 1987).

It was not until 1882, that Robert Koch identified and described the tubercle bacillus and its causative role in TB (Maher, 2009); and 28 years later, in 1900, when Albert Calmette and Camille Guérin began their research for an anti-tuberculosis vaccine at the Pasteur Institute in Lille (Luca & Mihaescu, 2013). In 1919, the vaccine was developed and named Bacille Calmette-Guerin (BCG) and was used in humans for the first time in 1921 (Luca & Mihaescu, 2013). Another breakthrough in controlling TB came in 1952, when isoniazid, an effective chemotherapy for TB became available (Ryan, 1992) followed by Rifampin or Rifampicin in 1968 (Sensi, 1983).

Before the advent of a vaccine and drugs, TB prevalence and mortality rates in Europe and America, started to decline in the early and mid-19th century (Daniel, 2006). This downward trend continued in high income countries (Dye, Lönnroth, Williams, & Raviglione, 2011). The factors that contributed to this decline are contentious, but are likely to include improved nutrition (Cegielski & McMurray, 2004; Grundy, 2005; McKeown & Record, 1962), better standards of living (McFarlane, 1989), and the isolation of infected individuals (Davies, Tocque, Bellis, Rimmington, & Davies, 1999; Wilson, 1990).

In the 1990s, as incidence and prevalence rates began to decline in high income countries, due to the introduction of the vaccine and drugs, there remained pockets of high incidence rates in the poorest area of some large cities. The occurrence of these pockets of high incidence rates has shown the importance of maintaining public health funding against this disease (Macaraig, Burzynski, & Varma, 2014). This further underpins the importance of both good public health and access to vaccines.

New York City in the United States of America (USA) is an example where a city had implemented successful TB prevention and control interventions and was then followed by a TB epidemic. For decades, the incidence of TB disease and mortality due to TB in New York declined; this is believed due to interventions like the Directly Observed Treatment, short-

course (DOTS) and infection control that were implemented by the city (Frieden, Fujiwara, Washko, & Hamburg, 1995). After successful control of TB in New York City, funding for TB control from the federal and state governments and locally from the city had been reduced in the 1970s and did not recover, even as TB rates had risen (Coker, 1998).

Part of this thesis is to review the quality of TB and ART/HIV policy guidelines. The quality of information in the policy guidelines can have an impact on the outcomes of TB control activities. Again, New York City is an example where it had a change in policy regarding reducing funding to the TB programme (as explained above) in which surveillance was one of the components (Frieden et al., 1995). It could be argued that this change in policy led to an increase in TB rates.

Contrary to what was observed in high income countries, no downward trend was observed in most of the low income and lower middle income countries, even after the introduction of effective chemotherapy (Ejeta, Legesse, & Ameni, 2013). In 2018, two thirds of new TB cases globally occurred in eight countries, of which seven are categorised as low income and lower middle income countries. As mentioned earlier, these eight high burden countries are: India (27%), China (9%), Indonesia (8%), the Philippines (6%), Pakistan (6%), Nigeria (4%), Bangladesh (4%), and South Africa (3%) (WHO, 2019).

To further add to the problem of high TB incidence over the years, multi-drug resistant TB developed. Isoniazid and Rifampicin are the two most active (most potent first line) anti TB drugs. Resistance to these two most powerful first line anti TB drugs is referred to as multi-drug resistant TB (MDR-TB);whereas resistance against isoniazid, rifampicin, injectable drugs, and quinolones is known as extensively drug-resistant strains (XDR-TB) (Zellweger, 2015). Multi-drug resistant TB and XDR-TB are thought to have emerged as a result of non-adherence to anti TB-drug regimens (Dharmadhikari, Smith, Nardell, Churchyard, & Keshavjee, 2013). Non-adherence may be because TB patients are unable or unwilling to take their drugs as prescribed due to the long period (six months) the treatment regime takes (Wurie, Cooper, Horne, & Hayward, 2018). In 2018, there were an estimated 484 000 (range, 417 000-556 000) new cases of multidrug-resistant TB (MDR-TB) with 78% of these people estimated to have rifampicin-resistant TB (RR-TB) (WHO, 2019) globally. Tuberculosis rates in low income and lower middle income countries have been exacerbated by the emergence of MDR-TB (Zellweger, 2015).

During the last quarter of a century, epidemiological trends of TB have been affected by the HIV epidemic. HIV infection is now the most important predisposing factor for the development of active TB. HIV is a predisposing factor for TB because it targets CD4 T-lymphocytes and reduces cellular immune function (Harries & Zachariah, 2008), which then renders the host unable to kill or contain the bacteria moreover leading to the reactivation and multiplication of the bacteria (Gough & Kaufman, 2011). Although high TB rates have been mainly attributed to HIV (WHO, 2008, 2009), it may be argued that the continued presence of TB in countries where the prevalence of HIV is low, is an indication that there are other factors associated with TB transmission; for instance, delayed diagnosis, uncompleted treatment, migration (movement of people from one place to another) and low SES (WHO, 2008). Risk factors for TB will be discussed in detail later in this chapter.

2.5 Diagnosis of TB

For decades, research has been conducted to develop various TB diagnostic techniques. It can be argued that this has led to a continued improvement in TB diagnosis due to new innovations (Cheon et al., 2016). The main methods used for TB diagnosis are microbiological, which could either be microscopy or culture-based technologies and immunological methods. Microscopy of sputum smear has been the primary TB diagnostic method although rapid detection of TB is difficult in clinical practice because only 44% of all new cases (and only 15-20% of children) (Lange & Mori, 2010; Newton, Brent, Anderson, Whittaker, & Kampmann, 2008) are identified by the existence of acid-fast bacilli (AFB) in the sputum smears. Microscopy of TB sputum is a simple inexpensive technique with a high specificity (Singhal & Myneedu, 2015).

In comparison to the sputum smears, the culture method is more accurate and sensitive. It is because of its accuracy that the culture-based technology has become a gold standard technique for clinical and research diagnosis of active TB (Cheon et al., 2016). Another diagnostic method used in South Africa is the GeneXpert System which uses the cartridge-based Xpert MTB/RIF (Xpert) assay which rapidly detects *Mycobacteria tuberculosis* (Meyer-Rath et al., 2012).

The other diagnostic tests—the tuberculosis skin test (TST) and interferon-γ release assay (IGRA)—depend on the immunological reaction of the host and are widely applied for the diagnosis of both active TB and latent TB infection (Cheon et al., 2016). The TST results must be interpreted with caution as there is a potential for false negative results among those that may be malnourished and with low immunity. Furthermore, there are some vaccines such as

the ones for polio, yellow fever and BCG vaccination that may also yield false positive results (American Thoracic Society and CDC, 2000).

2.6 Treatment of TB

According to the WHO, successful treatment of TB aims to ensure that TB patients are cured, their quality of life is restored as well as being productive again, and death that may arise as result of active TB is prevented. Furthermore, successful treatment aims to prevent the reactivation of TB, reduce infection of TB to others and prevent drug resistant TB from developing and being transmitted to others (WHO, 2010b). Successful treatment is critical for South Africa in order to reduce the prevalence of both MDR-TB and XDR-TB as earlier outlined in the section for TB epidemiology in South Africa. There are a number of TB drugs that are available for the treatment of TB. These anti TB drugs are usually administered over a six month period (WHO, 2016b). The anti TB drugs that are currently in use are Isoniazid, Rifampicin, Pyrazinamide, Ethambutol, and Streptomycin (WHO, 2010b). For treatment to be effective, the drugs should be taken under supervision through DOTS which has a potential of curing 95% of TB cases (Bell, Rose, & Sacks, 1999; Pape, 2005; Wandwalo, Kapalata, Egwaga, & Morkve, 2004). In South Africa, the standard treatment regimen for new cases starts with an intensive phase of daily medication with Isoniazid, Rifampicin, Pyrazinamide, and Ethambutol for two months which is then followed by Isoniazid and Rifampicin for four months (Department of Health, 2014). There are five possible TB treatment outcomes. These are; cured who is a patient whose baseline smear (or culture) was positive at the beginning of the treatment and is smear/ culture negative in the last month of treatment and on at least one previous occasion at least 30 days prior; treatment completed outcome which is when a patient whose baseline smear (or culture) was positive at the beginning and has completed treatment but does not have a negative smear/culture in the last month of treatment and on at least one previous occasion more than 30 days prior; treatment failure which is when a patient whose baseline smear (or culture) was positive and remains or becomes positive again at 5 months or later during treatment; treatment default who is a patient whose treatment was interrupted for two consecutive months or more during the treatment period, and died is where a TB patient dies for any reason during the course of TB treatment (Department of Health, 2014).

2.6.1 Contact tracing

In addition to treatment, identifying and assessing people who have been in contact with individuals infected with pulmonary TB, is a recommended component of TB control programmes in many low-incidence countries (Morrison, Pai, & Hopewell, 2008). Close

contact for at least 4 hours in a 24-hour period (J. E. Golub et al., 2001) with an infected individual is considered to put that person at risk of acquiring TB and once infected, the infection can progress to active TB. Investigations of contacts in high incidence countries are based on a number of international guidelines and recommend prophylaxis using isoniazid for those children below five years who are exposed but without active TB (Morrison et al., 2008). However, TB contact investigation in high incidence countries is generally given a low priority, partly because of the workload that arises as a result of the large number of active cases that are of high priority for treatment in any TB control programme and lack of resources to do contact tracing for all (Morrison et al., 2008). Contact tracing has proved to be a very important tool in the current COVID-19 pandemic. In order to reduce the spread of COVID-19, as previously mentioned, contacts are traced, tested, and self-isolate, especially if they are positive.

2.6.2 Barriers to TB treatment

There are number of TB services including treatment, that have cost implications to individuals as well as households, with these mostly affecting the poor which leads to barriers to health care. These challenges have implications as they can potentially lead to an undercount of the actual TB cases. Specialised TB clinics, TB diagnosis and treatment services are often located at tertiary levels of health services and may not be integrated into primary level services (Martinez, 2005). As a result, this tends to increase the distance to travel for those individuals living in rural areas, making it difficult for them to access diagnostic and treatment services. Travelling to TB services may be difficult in settings with bad roads or with no public transportation. Both women and men may experience barriers in accessing TB services (Martinez, 2005). For working men and women, the fear of losing their job may discourage them from seeking care, with a resultant delay in TB diagnosis and treatment. Some men and women may not access TB services due to limitations in their travel and financial resources (Martinez, 2005).

2.7 Tuberculosis epidemiology

2.7.1 Global epidemiology of TB

Tuberculosis is a major global public health challenge being the second most common cause of death due to an infectious disease, next only to HIV/AIDS (Lopez, Mathers, Ezzati, Jamison, & Murray, 2006; WHO, 2014). Ever since the WHO declared TB a global public health emergency in 1993, in most parts of the world TB mortality rates are reported to have

decreased by 45% since 1990 and TB prevalence rates have declined by 41% over the same period (WHO, 2014). Tuberculosis mortality has decreased globally (Dolin, Raviglione, & Kochi, 1994).

Reliable estimates for global TB incidence, prevalence, and mortality have not been achieved as these are based on the quality of available surveillance data. In addition, there is uncertainty whether TB treatment has had any form of significant influence on TB case fatality rates (Corbett et al., 2003; Dye, Scheele, Dolin, Pathania, & Raviglione, 1999; Schaaf & Zumla, 2009). In 2018, it was estimated that there were 10.0 million (range, 9.0 -11.1 million) new TB cases and 1.2 million (range, 1.1-1.3 million) TB deaths among HIV- negative people; and an additional 251 000 million (range, 223 000-281 000 million) among HIV-positive people (WHO, 2019). In line with the discrepancies in HIV incidence and prevalence, which have occurred previously, there are still inequities that are evident from exploring TB epidemiology. Although globally, TB incidence rates have been decreasing (WHO, 2014), in 2018, out of the estimated 10.0 million new TB cases globally, more than half (62%) were in the South East Asia and Western Pacific regions with both India and China accounting for 36% of the total TB cases. In comparison, other regions of the world had far fewer TB cases, with the Eastern Mediterranean region accounting for only 8%, the European Region 3% and the Americas 3% as depicted in Figure 2.1 (WHO, 2019). In 2018, the WHO estimated that out of the 10.0 million people who developed TB, 24% were residents of African countries, which is home to approximately 11% of the world's population. In addition, Africa had the highest estimated rates of cases and deaths relative to the population (WHO, 2019).

In 2016, almost 7 million people with TB were notified globally. This has been increasing since 2013 (WHO, 2017). An increase in new TB cases is usually associated with factors that include population growth (Vynnycky, Borgdorff, Leung, Tam, & Fine, 2008), ageing of the world population, HIV (Corbett et al., 2003) and multi-drug resistant TB (MDR-TB) (Lönnroth et al., 2010), and SES (Lönnroth et al., 2009; Muniyandi et al., 2007). The next section will discuss the epidemiology of TB in sub-Saharan Africa.

Figure 2.1: *Global Estimated TB Incidence Rates, 2018 (WHO, 2019)*
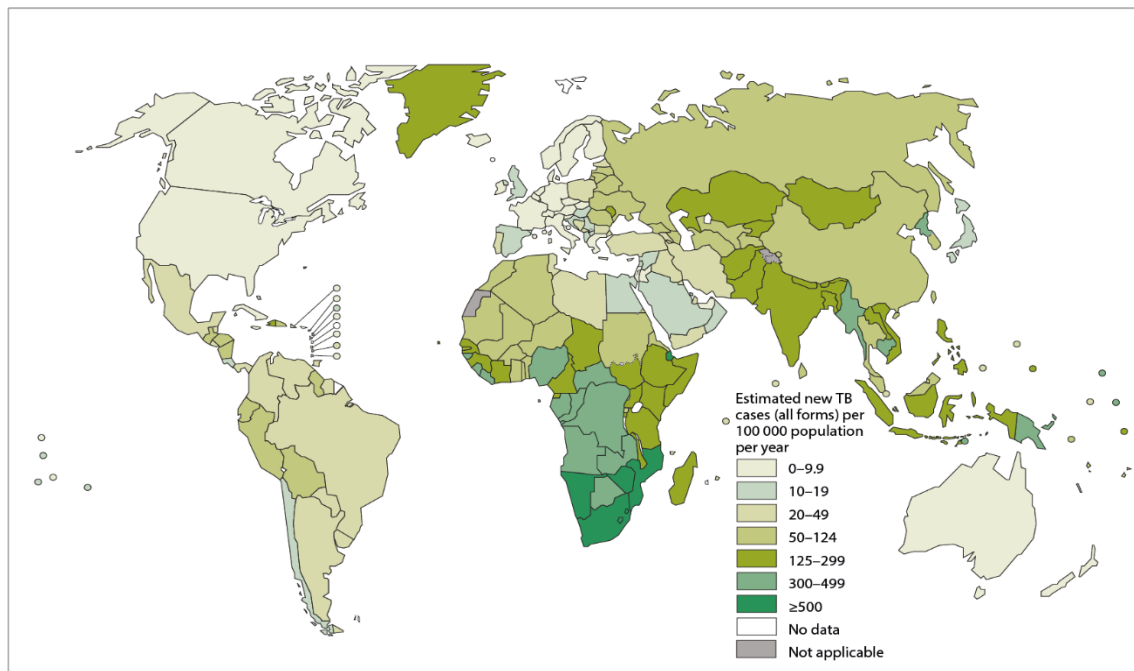
2.7.2 Epidemiology of TB in Sub-Saharan Africa

In sub-Saharan African nations, the incidence of TB has escalated over the past three decades, with an annual reported incidence doubling from 173.6 to 351.7 per 100 000 population between 1990 and 2007 (WHO, 2009). The doubling of TB incidence in sub-Saharan African nations has been mainly attributed to the link between TB and HIV/AIDS (Dye, Scheele, Dolin, Dphil, et al., 1999). More than 10 years ago, the scourge of TB in the African region did not attract much attention but it does today because the burden of TB in sub-Saharan Africa remains high as global rates are declining (Cauthen, Pio, & Dam, 2002). The increase in TB burden was more in eastern and southern Africa countries—the same countries that happen to be the most affected by HIV (Dye, Scheele, Dolin, Dphil, et al., 1999). In 2015, the proportion of TB patients that were co-infected with HIV was highest in residents of the African region accounting for 31% globally, while exceeding 50% in parts of southern Africa (WHO, 2016a). HIV, air pollution, malnutrition, overcrowding and poor access to health services have all led to a high incidence of TB in low income and lower middle income countries (Dye & Floyd, 2006). These will be discussed in more detail in the section for risk factors for TB.

The African region has continued to carry the highest burden of TB with 275 per 100 000 population in 2015, accounting for approximately a quarter (26%) of the total global TB cases that were notified (WHO, 2016a). The three countries with the highest estimated TB incidence rates in the African region are located in southern Africa and are; South Africa, Lesotho, and Mozambique, with estimated TB incidence rates of 834 per 100,000, 788 per 100,000, and 551 per 100,000, respectively. Overall, most countries in sub-Saharan Africa have over 150 annual TB incident cases per 100,000 (WHO, 2016a). Moreover, more than 50% of the high TB burden countries are reported to be in the African region (WHO, 2015a).

Tuberculosis can be a relatively early manifestation of HIV infection and it is also the leading cause of death among HIV-infected patients in Africa (Ansari et al., 2002; Grant, Djomand, & De Cock, 1997; Lucas et al., 1993; Rana et al., 2000). In 2014, of the 9.6 million people who developed TB globally, an estimated 1.2 million (12%) were HIV-positive with the African region accounting for 74% of these cases. The number of deaths of TB patients co-infected with HIV peaked at 570 000 in 2004 and declined to 390 000 in 2014 (WHO, 2015). In 2013, approximately four out of every five HIV-positive TB cases and TB deaths among people who were HIV-positive, were in Africa (WHO, 2014). Similarly, during this period, the proportion of TB cases co-infected with HIV was again highest in Africa. Overall, 34% of TB cases were estimated to be co-infected with HIV in Africa, which accounted for 78% of TB cases among people living with HIV globally. In southern African countries, more than half of the TB cases were co-infected with HIV (WHO 2014).

The high rates of HIV and TB co-infection have prompted calls for the mainstay of TB control (prompt diagnosis and treatment with DOTS) to be changed, as it is suggested that it is not possible to control the TB epidemic in sub-Saharan African countries without treating those co-infected with HIV (Corbett, Marston, Churchyard, & De Cock, 2006). The HIV epidemic has challenged DOTS as the only TB control approach for the African region, because even rigorous programmes are unable to compensate for the rising susceptibility to TB with an increase in HIV prevalence (Corbett et al., 2006). Furthermore, in HIV-infected individuals with clinically symptomatic TB, the risk of death is about three to seven-fold higher than in those individuals who are HIV negative (Nunn et al., 1992; Perriëns et al., 1991) while in those individuals with AIDS, developing TB will increase the overall mortality by one-third (Perneger, Sudre, Lundgren, & Hirschel, 1995).

Notwithstanding the importance of early detection and treatment of TB as key intervention strategies for TB elimination, there still exists challenges of poor detection, under reporting, delayed treatment initiation, and non-completion globally (WHO, 2016a). Although the treatment success rate of TB in Africa is lower than the expected target of 90%, there was an increase from about 70% in 2000 to 81% in 2014 (WHO, 2016a).

2.7.3 TB epidemiology in South Africa

Due to the dearth of reliable TB estimates, this thesis looks at the quality of both the surveillance and mortality TB data in South Africa for the period 2005-2015. South Africa was among the eight countries with the reported highest burden of TB disease in the world, with an estimated annual incidence of 454 000 cases of active TB in 2015, an increase of 400% over the last 15 years (WHO, 2016a). This same trend has continued to date (WHO, 2019). An estimated 60-73% of the 454 000 incident cases in South Africa had both HIV and TB infection. Additionally, South Africa has one of the world's worst TB epidemics fuelled by HIV. Among the eight countries with the highest burden of TB, South Africa has one of the highest estimated incidence and prevalence of TB, the largest number of HIV-associated TB cases, and the second highest number of diagnosed MDR-TB cases (Churchyard et al., 2014).

In 2002, South Africa had an estimated TB incidence of 493 cases per 100 000 population with KwaZulu-Natal, Eastern Cape, and Western Cape provinces having the highest number of TB cases (Barr, Padarath, & Sait, 2005). There has been a steady increase in the incidence of TB in South Africa, from 971 per 100 000 in 2009 to 1 003 per 100 000 in 2012 (Republic of South Africa, 2013; The World Bank, 2016). The HIV/AIDS epidemic has increased these rates; for instance, in 2012, the HIV incidence was 1.07 % while the prevalence was 10.9% in 2008 and 12.6% in 2012 (Human Sciences Research Council, 2014).

The emergence of both, MDR-TB and XDR-TB has been of major concern to TB control efforts in South Africa (Dharmadhikari et al., 2013). It has been estimated that South Africa has an annual case load of 13 000 MDR-TB cases thereby placing South Africa among those countries where MDR-TB is highly prevalent (Dharmadhikari et al., 2013). In fact, in 2013, South Africa alone accounted for 40% of all MDR-TB cases worldwide (WHO, 2014).

Notwithstanding the introduction of DOTS and the TB control interventions, the TB epidemic is not controlled in South Africa which is evident by the high estimated TB indicators. For instance, the most recent available estimates in 2018, showed that South Africa had a total population of 58 million people with the incidence rates of all forms of TB estimated to be

520 per 100 000 population (WHO, 2019). The most recent estimates for the prevalence of TB disease are in 2013; this is mainly because TB prevalence is neither an indicator in the SDGs nor a high-level indicator of the End TB Strategy. In addition, there are no global targets that have been set for the period 2016-2035 (WHO, 2014, 2019). Furthermore, indirect estimates of TB prevalence suffer from considerable uncertainty because they are derived from incidence and assumptions about disease duration. Therefore, in 2013, TB prevalence for South Africa was estimated to be 760 per 100 000 population (WHO, 2014). South Africa still falls below its targets of 85% successful treatment among the new smear-positive cases initiated on treatment, and a case detection rate of at least 70% as shown in Table 2.1.

Table 2.1: *Estimated TB Indicators, South Africa, 2018 (WHO, 2019)*

Indicator	Total
Total population (million)	58
Incidence rate of all forms of TB (per 100 000 population)	520
Mortality rate of all forms of TB (per 100 000 population, excluding deaths among TB/HIV co-infected)	37
Mortality rate of all forms of TB (per 100 000 population, among TB/HIV co-infected)	73
Notification rate of all forms of TB (thousands)	235
Case detection rate all forms of TB (percentage)	69
Successful treatment of 2018 cohort (percentage)	77

2.8 Risk factors for TB

Individuals that are exposed to a sputum positive TB case are at a higher risk of getting a TB infection, with this risk depending on several factors including the environment, duration of exposure, and as mentioned under the section of the natural history of TB, it also depends on the immune status of the susceptible individuals. There have been a number of studies that have been done to identify TB risk factors (Cailhol, Decludt, & Che, 2005; Corbett et al., 1999; Godfrey-Faussett & Ayles, 2003; Reid et al., 2006). In the next sub sections, the researcher will discuss each one of the identified risk factors in more detail.

2.8.1 HIV

A prospective study of 326 miners, conducted in South Africa in 1995, established HIV as a risk factor for TB recurrence (Sonnenberg et al., 2001). HIV has been identified as the most potent risk factor for developing active TB (Corbett et al., 2003) and it plays a significant role in the reactivation of latent infection of TB leading to the development of active TB (Bucher et al., 1999). Through studies, especially in those countries where the prevalence of HIV is

notably high, it has been established that there is a strong association between the prevalence of HIV infection and that of spatial and temporal variation in TB incidence (Corbett et al., 2003). Studies that have been conducted in both high (S. Lawn, D., Bekker, Middelkoop, Myer, & Wood, 2006) and low TB burden countries (DeRiemer et al., 2007) have associated HIV infection with an increase in the number of new TB cases.

2.8.2 Alcohol

Alcohol has also been identified as a potent risk factor for TB (Lönnroth, Williams, Stadlin, Jaramillo, & Dye, 2008) as a result of its effects on the immune system (Szabo, 1997). Alcohol as a risk factor for recent transmission of TB in both high and low TB incidence countries was identified through a meta-analysis of molecular epidemiological studies with (OR=2.6, CI=2.13-3.3) and (OR=1.4, CI=1.1-1.9) for high and low TB countries respectively (Fok, Numata, Schulzer, & FitzGerald, 2008). Similarly, a systematic review of three cohort and 18 case control studies established that the risk of developing active TB is potentially increased (RR= 2.94, 95% CI =1.89-4.59) among those individuals who consume alcohol in excess of 40g alcohol per day (Lönnroth et al., 2008).

2.8.3 Smoking

Tobacco smoking is a major risk factor for TB. Several systematic review studies (Maurya, Vijayan, & Shah, 2002) have shown the association between smoking and TB to be higher among smokers than non-smokers with a relative risk (RR) of 2.3-2.7 (Bates, 2007). Similarly, a systematic review and meta-analysis of six studies established an effect of smoking on Latent TB infection even after an adjustment for alcohol (OR=1.76, CI=1.43-2.16) (H. Lin, Ezzati, & Murray, 2007). Furthermore, the association between smoking and TB has been linked to the impairment of the ability to clear mucosal secretion (Houtmeyers, Gosselink, Gayan-Ramirez, & Decramer, 1999), a reduction in the functioning of the alveolar macrophages as phagocytes, and a weak immune response (H. Wang et al., 2003). An association between smoking and TB was further demonstrated in an animal study where mice were exposed to cigarette smoke followed by infection with *Mycobacterium tuberculosis*. The results of this study showed elevated amounts of viable *Mycobacterium tuberculosis* bacilli in the lungs and spleen with a lower adaptive immunity in the exposed mice (Shang et al., 2011).

2.8.4 Malnutrition

Another association that has been documented is that of TB and body wasting. A number of studies have shown that malnutrition impairs host immunity thereby increasing the risk of developing TB disease (Cegielski & McMurray, 2004; Chandra, 1997; Chandra & Kumari, 1994; Hill et al., 2006; Lönnroth et al., 2008; S. Martin, J. & Sabina, 2019; Odone, Houben,

White, & Lönnroth, 2014). The BCG vaccine trials that were carried out in the USA in the late 1960s, demonstrated an association between malnutrition and TB. They estimated that children who were malnourished were more likely to develop TB than those that were not (Comstock & Palmer, 1966). Although these findings were not disputed, some researchers commented that despite the existence of evidence of an association between malnutrition and TB, there was a need to define the risk relative to specific levels of malnutrition (Cegielski & McMurray, 2004).

2.8.5 Socio economic status

The association between TB and SES has long been established (Waaler, 2002). The effect of rapid urbanisation (Dye & Williams, 2010; Eisenberg et al., 2007) seen in low income countries and the SES of individuals has been shown to have an increased risk for TB infection. Tuberculosis has long been associated with poverty and this was recognised before the availability of treatment, when there was a decline in TB in developed countries as a result of improved living conditions (Lönnroth et al., 2009). It has been identified that the burden of TB has an inverse relationship with SES between and within countries, with the highest risk being amongst the poorest people (Lönnroth et al., 2009; Muniyandi et al., 2007). It may further be argued that people with low SES may be exposed to several risk factors like malnutrition and alcohol, which in turn predisposes them to the risk for TB. Similarly, individuals with lower SES are more likely to be exposed to crowded, poorly ventilated places with limited safe cooking facilities which can put them at further risk of developing TB (Lönnroth et al., 2009; Muniyandi et al., 2007).

2.8.6 Air pollution

Another TB risk factor is indoor air pollution. It has been observed that more than 85% of cooking in low income countries uses solid fuels (K. R. Smith, 2002) which produce smoke. Exposure to biomass smoke increases the risk of respiratory diseases such as TB (Po, FitzGerald, & Carlsten, 2011). This was confirmed by results of case control studies that were conducted in India and Brazil that identified firewood or biomass smoke as an independent risk factor for TB disease (Kolappan & Subramani, 2009; Mishra, Retherford, & Smith, 1999; Pérez-Padilla, Pérez-Guzmán, Báez-Saldaña, & Torres-Cruz, 2001; Pokhrel et al., 2009). Although there is a dearth of data on how biomass smoke causes chronic pulmonary diseases (Diaz, Koff, Gotway, Nishimura, & Balmes, 2006), studies conducted in animals revealed that acute wood smoke affects the functioning of macrophage phagocytes, surface adherence (Fick, Paul, Merrill, Reynolds, & Loke, 1984), and bacterial clearance (Zelikoff, Chen, Cohen, & Schlesinger, 2002). In addition, biomass combustion releases large particulate matter like

carbon monoxide, nitrogen oxide, formaldehyde, and polyaromatic hydrocarbons which get deposited deep into the alveoli causing damage (Boman, Forsberg, & Järvholm, 2003; Bruce, Perez-Padilla, & Albalak, 2000; Ezzati & Kammen, 2002). South Africa has informal settlements that lack proper sanitation, electricity, and ventilation. A lack of electricity means that the inhabitants of these informal settlements cook using firewood, waste from animal farming, and coal. These conditions are usually associated with a number of health risks which may include respiratory diseases (Richards, O' Leary, & Mutsonziwa, 2007).

2.8.7 Risk factors for reactivation of TB

There are risk factors associated with reactivation which occurs when those individuals that were exposed to the bacilli, and had successfully responded to the infection and contained it for a period of time, develop TB disease later as a result of changes in their body defence mechanism (Borgdorff, Behr, Nagelkerke, Hopewell, & Small, 2000). Known risk factors for reactivation of latent infection as identified by epidemiologic studies, include: co-infection with HIV, malnutrition, tobacco smoking, indoor air pollution, alcoholism, silicosis, insulin dependent diabetes, renal failure, malignancy, and immune suppressive treatment, such as glucocorticoids (Horsburgh, 2004; Jick, Lieberman, Rahman, & Choi, 2006; P. L. Lin & Flynn, 2010; Lönnroth et al., 2008). The HIV infection and treatment with tumour necrosis factor (TNF) inhibitors are the most well described risk factors for TB reactivation (Horsburgh, 2004; Jick et al., 2006; P. L. Lin & Flynn, 2010; Lönnroth et al., 2008). In addition, migration is another risk factor for the reactivation of TB, this may be attributed to poor living conditions and SES of the migrants (Dhavan, Dias, Creswell, & Weil, 2017; Lönnroth et al., 2009).

2.8.8 Occupation

The type of occupation is another TB risk factor. South Africa's mineral miners are one group known to be at a particularly high risk of both HIV and TB (J. Murray et al., 2011). To date, TB is considered one of the most serious health problems facing mine workers, especially in gold mining. Apart from trauma, TB has been identified as the major single cause of mortality among mineworkers (Kleinschmidt & Churchyard, 1997). In addition to mining, other occupations associated with TB are health care workers and people working in agriculture. Agricultural workers are six times as likely to develop an active TB infection compared to other adults (Rosenman & Hall, 1996). It has been argued that there are a number of risk factors that expose agricultural workers to TB and these include; history of smoking (Oren et al., 2016), low SES of agricultural workers which exposes them to a lack of access to an adequate food diet and hunger, leading to malnutrition which is known to be associated with TB (Weigel, Armijos, Hall, Ramirez, & Orozco, 2007). However, because of their low SES this may limit

their ability to access health care facilities (Arcury & Quandt, 2007). Similarly, health care workers are at a higher risk for infection with *Mycobacterium tuberculosis* and of developing TB disease with the infection being most likely acquired from infected persons that have not yet been diagnosed or appropriately treated for TB (Baussano, 2011). A number of studies have established that annually there are more new TB infections among health care workers than in communities (Adams et al., 2015; McCarthy et al., 2015). In addition to undiagnosed or inappropriately treated TB, transmission may also be due to lack of personal protective equipment and overcrowding that is observed in some health care facilities, especially in low and middle income countries (Grobler et al., 2016).

2.8.9 TB and HIV co-infection

It has been established that there is an association between high prevalence rates of HIV and high TB prevalence rates. HIV is one of the most potent risk factors known to activate latent *Mycobacterium tuberculosis* infection as a result of the alteration of the immune response (Kwan & Ernst, 2011; Narasimhan, Wood, MacIntyre, & Mathai, 2013). In addition to increasing the risk of reactivating latent *Mycobacterium tuberculosis* infection (Bucher et al., 1999), HIV increases the risk of rapid TB progression soon after infection or reinfection with *Mycobacterium tuberculosis* (Corbett et al., 2003; Daley et al., 1992; Shafer, Singh, Larkin, & Small, 1995). Although those who are co-infected with TB may have typical symptoms of TB, a number of those individuals may have few symptoms or have symptoms that are not specific (Sterling et al., 2010).

For a person who is HIV-infected and co-infected with *Mycobacterium tuberculosis*, the risk of developing active TB reaches 5-10% annually (Girardi, Raviglione, Antonucci, Godfrey-Faussett, & Ippolito, 2000; Selwyn et al., 1989) instead of the 10-20% lifetime risk for an individual not infected with HIV (Sutherland, 1976; Vynnycky & Fine, 1997; WHO, 2007). However, the majority of individuals do not develop active TB as a result of an effective immune response. As immunity declines with age, these individuals will be at an increased risk of progressing into active TB due to a reactivation of a primary infection or an exogenous infection (Behr et al., 1999; Dye, Scheele, Dolin, et al., 1999).

2.9 History of HIV

It was in the 1980s when HIV was recognised for the first time as a new health condition. In 1981, cases of rare diseases were being identified among men who were having sex with men in New York and California; for example, Kaposi's Sarcoma and a lung infection called

Pneumocystis Carinii Pneumonia (PCP) (CDC, 1981; Hymes et al., 1981). Although no one knew why these cancers and opportunistic infections were spreading, there was an idea that an infectious 'disease' was causing them. In September 1982, the disease was named AIDS (CDC, 1982). The major transmission routes of the still unidentified 'AIDS agent' were described by January of 1983. The existence of heterosexual transmission of HIV was identified through reports of the presence of signs of immunodeficiency in female partners of men infected with AIDS in New York City (CDC, 1983). American researchers headed by Robert Gallo (Gallo et al., 1984) and French researchers headed by Luc Montagnier discovered the causative agent for AIDS giving it different names. In 1986, the International Committee on the Taxonomy of Viruses proposed a simple descriptive name for the causative agent: HIV (Cohen, 1987).

The discovery of the first two HIV/AIDS cases in the Republic of South Africa was revealed in 1982 (Ras, Simson, Anderson, Prozesky, & Hamersma, 1983). Both cases were Caucasian homosexual males who worked as cabin crew and had visited the USA on several occasions during their line of duty (Ras et al., 1983). The spread of HIV in South Africa and the neighbouring countries may have been deferred during the severe restrictions on people's movement under Apartheid. However, the system of migrant labour, especially on the gold mines, with a resultant breakdown of family life and an increase in extra-marital relationships, mostly with migrant sex workers from neighbouring countries, led to the current rapid spread of HIV (Williams et al., 2015).

2.10 HIV and TB programmes in South Africa

An important component of this thesis is the review of TB and HIV/ART policy documents; therefore, this section plays an important role in discussing the integration of TB/HIV activities aimed at reducing the burden of TB in people living with HIV in South Africa and vice versa (reducing the HIV burden in TB patients). HIV has been identified as being responsible for a large increase in the proportion of individuals with smear-negative pulmonary and extra pulmonary TB. These individuals have poor treatment outcomes, including a high level of premature mortality in comparison with HIV negative, smear-positive pulmonary TB persons (Department of Health, 2014). This is as a result of late presentation, late diagnosis, and a delayed initiation of treatment. Therefore, rapid diagnosis of both smear positive pulmonary TB (PTB) and smear negative pulmonary, and extra pulmonary TB and early initiation of treatment are key to the reduction of TB mortality in people living with HIV (Department of Health, 2014). Co-infected persons have a high mortality due to the disease progressing rapidly, delayed diagnosis, and possible opportunistic infections. Appropriate TB case management

together with comprehensive HIV care for the co-infected individuals prolongs their lives (Department of Health, 2014).

In 2003, South Africa developed a policy guideline that paved the way for starting a free national ART programme (Karim, Churchyard, Karim, & Lawn, 2009). However, TB patients were not prioritised for ART until 2009. This delay in prioritising TB patients may have contributed to their persistently high mortality rates. Since then, South Africa has recognised the importance of providing appropriate HIV care to TB and HIV co-infected persons in order to reduce their morbidity, mortality, and improve treatment outcomes (Department of Health, 2014). As a result, there are a number of programmes and policies in South Africa that have been developed over time to target TB and HIV co-infected people. The programmes include fast tracking ART initiation, a rapid plasma reagin (RPR) test to screen for syphilis, PAP smears for all HIV positive women, and symptomatic screening for sexually transmitted infections (STIs). Reproductive health care which emphasises effective contraception whilst on TB treatment coupled with using condoms for the prevention of transmission of HIV and thus avoidance of re-infection is another programme provided. Furthermore, nutritional supplement is provided as well as Cotrimoxazole prophylaxis against opportunistic infections (Department of Health, 2014). Details of the HIV/ART policy guidelines will be discussed in the chapter for reviewing policy guidelines.

2.11 Role of surveillance and disease control systems

Surveillance is the corner stone of all efforts that are undertaken to understand the control and prevention of disease occurrence. It is, therefore, important to have a disease surveillance system that is functioning well, because it will provide timely and reliable information that is required for planning, implementation, monitoring, and evaluation of public health interventions (B. C. K. Choi, 2012). In other words, an efficient surveillance system should eventually lead to public health action. Unlike in low income countries, for example in sub-Saharan Africa, surveillance systems in high-income countries have improved over time and widened their scope. In addition to monitoring infectious diseases, surveillance systems in high income countries now include the examination of the role of biological, psychosocial, and environmental factors as part of supporting health promotion and guiding non-communicable disease and mental illness prevention activities (B. C. K. Choi, 2012). Surveillance systems provide health and disease data that are needed to inform key public health stakeholders like the WHO. These data enable stakeholders to take public health action by planning and implementing more effective, evidence-based public health policies and strategies relevant to

the prevention and control of diseases (Amato-Gauci & Ammon, 2008). The following section summarises TB policies and strategies that have been developed and implemented to control TB globally, in sub-Saharan Africa, and South Africa.

2.12 Tuberculosis policies and strategies

The WHO (1994) has developed a number of policies aimed at controlling the spread of TB. Following the declaration of TB as an emergency in 1993, the WHO developed the DOTS strategy a year later. The aim of this strategy is to guide countries towards effective TB control in the wake of recognising that TB had been ignored and poorly managed (WHO, 1994). The DOTS strategy has five components; commitment from national governments with provision of continued funding, adequate case detection, recommended standardised treatment, a regular drug supply, and reporting system. Since its development, the DOTS strategy has remained the main intervention for TB control; however, its scale-up in some WHO member countries has been constrained by weak political commitment (Atun, Weil, Eang, & Mwakyusa, 2010). As a result, the Stop TB Initiative was launched in 1998 which consists of all key stakeholders and any country with a heavy TB burden.

The Stop TB Partnership was developed in 2000 as a worldwide development to utilise social and political activity in halting the global spread of TB (WHO, 2010a). The goal of the partnership is to eliminate TB as a public health issue and eventually, a world that is free of TB. In 2001, the Stop TB Partnership inaugurated the Global Plan to Stop TB 2001-2005 (WHO, 2001) which was followed by a second plan for 2006-2015. The targets for the second plan were aligned with the MDGs with the aim of reducing TB prevalence and deaths to 50% by 2015, with the baseline being the 1990 indicators (WHO, 2006b). Between 2000 and 2013, TB prevention, diagnosis, and treatment interventions saved an estimated 37 million lives globally. Despite efforts to reduce the burden of TB, the MDG target for TB was not met, with TB mortality rate decreasing by 45% and the prevalence rate by 41% between 1990 and 2013 (United Nations, 2015).

Following the end of the MDGs, the WHO developed the post 2015 TB strategy, "Towards TB elimination", with the aim of reducing the incidence of TB by 90% by 2035 (pre-elimination defined as less than 10 TB cases, all forms, per 1 000 000 population) and eliminating TB (defined as less than one TB case, all forms, per 1 000 000 population) by 2050 (WHO, 2015b).

2.12.1 Sub-Saharan Africa TB policies and strategies

The main intervention for TB control in sub-Saharan Africa is through the DOTS strategy. The strategy has been implemented in sub-Saharan Africa with a coverage of 84% (Dye et al., 2006). The estimated case detection rate by the DOTS programme in sub-Saharan Africa in 2005 was 48%, below the global average of 53%, and not increasing as quickly as the global average at the time (Dye et al., 2006). However, in 2010 this increased to 60% which was more than the global average (WHO, 2011).

Because efforts to control TB have been mainly through the implementation of the DOTS strategy, this requires political, administrative regulations and systematic monitoring measures for the successful implementation of DOTS. Political commitment is critical in promoting national and international collaboration that is important in addressing the technical and financial needs of the TB programme. Furthermore, political commitment, administrative regulations, and systematic monitoring measures all promote accountability for results at all levels of TB management and the health system at large. In addition, political commitment is important in supporting the overall structural changes that are crucial to improving the supply and distribution of health workers (WHO, 2020b).

The ability to identify TB patients is an important step in the five-point DOTS strategy; however, DOTS implementation has faced a number of challenges in sub-Saharan Africa, including: weak public health care systems, difficulties with Directly Observed Therapy (DOT) implementation, poor collaboration with the private health sector, and inadequate knowledge, awareness, and skills of health care providers (WHO, 2004). In countries where DOTS has been implemented properly, it has proved to be a very effective TB control strategy (Tumbo & Ogunbanjo, 2011). In other developing countries, like South Africa, DOT has successfully been implemented as has been reported in Cambodia and China, with as many as 84-95% and 93-97% of TB patients, respectively, successfully treated (Tumbo & Ogunbanjo, 2011).

2.12.2 South Africa TB policies and strategies

The South African Government adopted the DOTS strategy in 1996 and, in 1999, committed more resources to implement the DOT component. In addition, the TB control programme was prioritised at a national level (Ntshanga, Rustomjee, & Mabaso, 2009). Although DOTS coverage in South Africa increased from 22% in 1998 to 100% in 2006 (Tumbo & Ogunbanjo, 2011), there exists a discordance between the high DOT coverage, the low successful treatments, and the high rates of MDR-TB. It may be argued that DOT is not properly

implemented leading to low proportions of successful treatment outcomes (Ershova et al., 2014). A study conducted in the North West province of South Africa revealed that the percentage of TB patients that received DOT was as low as 56.8%, with coverage being much lower among TB retreatment patients (Ershova et al., 2014).

To tackle the TB epidemic, South Africa developed an integrated National Strategic Plan (NSP) for HIV, STIs, and TB (2012-2016), with targets to halve TB incidence and mortality by 2016 and no new TB infections, deaths, or stigma by 2032. In order to achieve the targets, South Africa has adopted policies like the '3Is' policy of Isoniazid preventive therapy (IPT), intensified case finding, and infection control. Another strategy used by South Africa is the multi-faceted TB screening programme. Introduced in 2011, the multi-faceted TB screening programme's focus was on high TB-burden districts, which included household contact tracing, HIV counselling and testing campaigns, community mobilisation, door-to-door enquiry in areas with a high burden of smear-positive TB, and screening of high-risk populations (Churchyard et al., 2014). Even though South Africa has put these policies in place, the TB burden remains high.

2.13 The national TB control programme of South Africa

In South Africa, the disease notification system is a national system that has been implemented throughout all provinces and its purpose is to collect certain data on specific notifiable medical conditions. The majority of the conditions are communicable diseases. The national Department of Health makes a decision to designate a condition as a notifiable medical condition. The notification system is guided by the Health Act No 63 of 1977 (Department of Health, 1999). Currently there are 29 medical notifiable conditions in South Africa and some of these, for example TB, have been further categorised into a number of clinical presentations of the disease.

The nine provinces of South Africa are each divided into district municipalities and sub districts/local municipalities. South African provinces are diverse with poverty varying greatly across the nine provinces and some groups experiencing more poverty than others. These groups are black Africans, female-headed households, the elderly, less educated individuals, those without employment, and the ones living in the rural areas in the provinces of KwaZulu-Natal, Limpopo, and Eastern Cape (P. Armstrong, Lekezwa, & Siebrits, 2008; Leibbrandt & Woolard, 1999; Statistics South Africa, 2017). Provinces like Western Cape and Gauteng are considered to be wealthy and, therefore, their inhabitants are not as poor as those of, for instance, Eastern Cape province (P. Armstrong et al., 2008).

Almost half (45%) of the South African population is still living on approximately $2 per day (the upper limit for the definition of poverty) while more than 10 million people live on less than $1 per day (the food poverty line); which means that more than 10 million people are likely not able to buy enough food to have an adequate diet (Leibbrandt, Woolard, Finn, & Argent, 2010; Mayosi & Benatar, 2014; Taylor, 2002). This has implications for TB infection which is associated with malnutrition and SES as discussed earlier. There is an inverse relationship between SES and TB; therefore, in these groups of people there is expected to be an increase in the number of TB cases which the national TB control programme (NTP) is expected to pick up through the surveillance system. These conditions of both malnutrition and low SES, it may be argued are playing a big role in the South African TB epidemic.

For over two decades South Africa's NTP has been monitoring TB case rates and treatment outcomes (Podewils et al., 2015). The targets of the NTP are to achieve at least an 85% successful treatment among the new smear-positive cases initiated on treatment, and a case detection rate of at least 70% (Department of Health, 2009). However, despite efforts towards TB control, the NTP has not yet achieved the targets with the successful treatment remaining low at 79% (Ershova et al., 2014) and the detection rate at 63% (The World Bank Group, 2016).

The NTP operates at five levels of intervention: national, provincial, district, sub district, and the health facility. Each level has its own functions. At the health facility level, suspected and confirmed TB cases are recorded on paper forms that are provided by the NTP (see Appendix B). After the patient's information is captured on the paper based TB register, it is sent to the sub-district office, where the information is entered into the ETR. The ETR was implemented country wide by the NTP over a decade ago. The ETR data are consolidated at each of the levels of the NTP in order to generate indicators for that particular level (Podewils et al., 2015) as shown in Figure 2.2.

Figure 2.2: *Information Flow for the NTP, South Africa (Podewils et al., 2015)*

```
                    ┌─────────────────────┐
                    │         TB          │
                    │  infection/symptoms │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │ Health facility     │
                    │ screening for       │
                    │ TB done at primary  │
                    │ health care level   │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │    TB diagnosis     │
                    └─────────────────────┘
                      │               │
                      ▼               ▼
        ┌─────────────────────┐ ◄──► ┌─────────────────────┐
        │ Health Facility     │      │ Health Facility     │
        │ Blue card given to  │      │ TB register         │
        │ the TB patient      │      │                     │
        └─────────────────────┘      └─────────────────────┘
                      │               │
                      ▼               ▼
                    ┌─────────────────────┐
                    │  Sub district ETR   │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │    District ETR     │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │   Provincial ETR    │
                    └─────────────────────┘
                               │
                               ▼
                    ┌─────────────────────┐
                    │    National ETR     │
                    └─────────────────────┘
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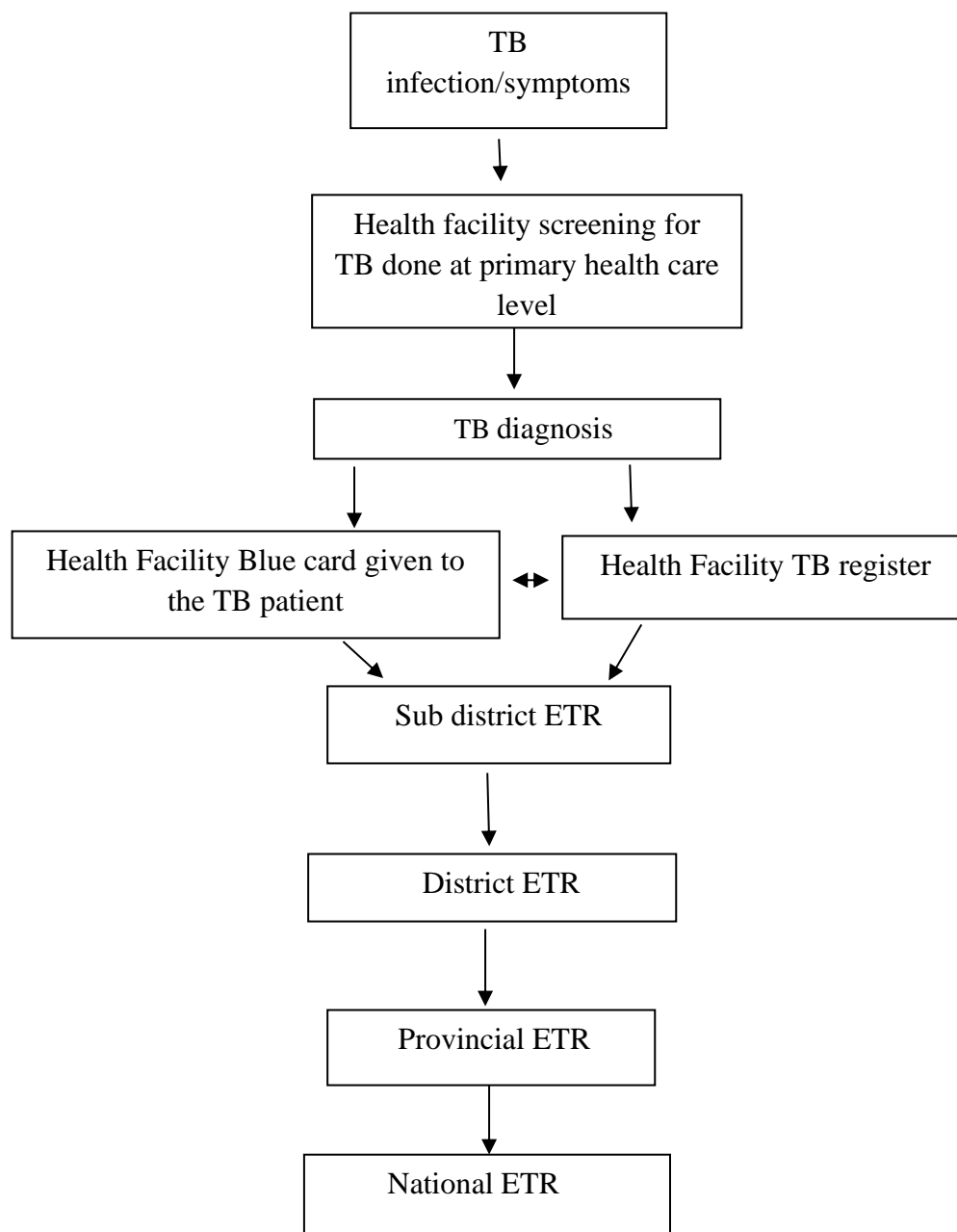
2.13.1 Challenges of the NTP

The South African NTP is faced with a number of challenges which include: inadequate programme management especially at the facility level, inadequate health systems that result in low case detection, poor continuity of care resulting in high levels of treatment interruption due high levels of client mobility, poor referral systems coupled with a lack of a unique identifier that can be used to track patients (Churchyard et al., 2014; Department of Health, 2009) and undocumented immigrants who may not present themselves to the health system due to the fear of being detected by Government authorities (Abera Abaerei, Ncayiyana, & Levin, 2017). Furthermore, the NTP is faced with challenges of poorly trained or supervised health

care personnel, non-adherence to protocols where healthcare workers may be unaware of or uninformed about protocols, poor record keeping, and poor data quality. Furthermore, there is a lack of data being analysed and used to improve the TB programme (Department of Health, 2009). Data quality has been affected by the incomplete understanding of TB indicators among some of the staff responsible for recording and reporting TB data (Podewils et al., 2015). In addition, there is a high turnover of staff responsible for capturing TB data (Churchyard et al., 2014). These challenges have major implications on the quality of data captured in the ETR.

2.14 Evaluation of surveillance systems

To enable a public health programme use good quality health information for evidence based decision making, it is paramount to put in place a high quality public health surveillance system (Hendrikx et al., 2011). An evaluation of a public health surveillance system should be performed in order to assess whether the system is meeting its aims (Teutsch & Churchill, 2000). The WHO categorised surveillance as one of the five critical components in its original Framework for Effective TB Control (the WHO DOTS strategy) established in 1994 (Nsubuga et al., 2006). The two roles of surveillance systems are to identify and prevent the spread of outbreaks of disease (control based surveillance) and to use the information collected on surveillance forms to develop public health policy (strategy based surveillance) (Baker, Easther, & Wilson, 2010). This means a TB surveillance system is a critical component of TB control and thus needs to be effective.

Surveillance evaluation seeks to ascertain whether a health event is monitored efficiently, examine how well the system is meeting its purpose and objectives (CDC, 2001). It is critical to regularly conduct evaluations of surveillance systems to ensure that the data that are produced are accurate, reliable, and able to guide public health programmes (CDC, 2001). The following sub section summarises the current CDC guidelines for evaluating public health surveillance systems.

2.14.1 Guidelines for the evaluation of surveillance systems
In 2001, as a response to the need for integration of surveillance and health information systems, establishment of data standards and facilitating the response of public health to emerging health threats, the CDC and Prevention published the Updated Guidelines for Evaluating Public Health Surveillance Systems. The main objective of the guidelines is to address the need for integration of surveillance and health information systems (CDC, 2001). While these guidelines outline broad components that should be considered, they are not specific to a particular surveillance programme or health event; therefore, they can be used for

a TB surveillance system, as is the case for this study (CDC, 2001). The guidelines aim to organise the process of evaluation of a public health surveillance system. Evaluation of public health surveillance systems should involve an assessment of the system attributes, including simplicity, flexibility, data quality, acceptability, sensitivity, positive predictive value, representativeness, timeliness, and stability (CDC, 2001). Public health surveillance systems are not the same in procedure, scope, purpose, and goals; therefore, an evaluation of the public health surveillance system must consider the objectives and those attributes that are critical for the functioning of the given system that is under evaluation. The CDC (2001) guidelines recommend a description of the eight attributes of the system, this is addressed in the next section.

2.14.2 Attributes of the public health surveillance system

This sub section provides a detailed description of each attribute of the public health surveillance system.

2.14.2.1 Simplicity

The simplicity of a public health surveillance system denotes its structure and ease of operation. Simplicity of a surveillance system is considered as the entire process from data collection up to the use of the data (CDC, 2001). To evaluate the simplicity of the public health system, a number of measures may be considered, including; the availability, amount, and type of data necessary for characterisation of the occurrence of the health related event under surveillance, amount and type of other data on cases (CDC, 2001). In addition, the level of integration with other systems, method of data collection, amount of follow-up that is necessary, data management and analysis, dissemination methods, staff training requirements, and time spent on maintaining the system may be considered (CDC, 2001).

2.14.2.2 Flexibility

In order for a public health surveillance system to be considered flexible, it means that it is capable of adapting to changing information needs or operating conditions with a minimum of additional resources (CDC, 2001). For flexibility to be evaluated, it requires a retrospective observation of how the surveillance system has responded to a new demand (CDC, 2001).

2.14.2.3 Data quality

Completeness and validity of the data recorded in the public health surveillance system reflects the quality of the data. Data quality may be assessed through the percentage of missing variables (CDC, 2001) as is the case for this study. However, a full assessment of the completeness and validity of the system's data might require a special study. Data values recorded in the surveillance system can be compared to "true" values through, for

example, a review of sampled data (Klevens, Fleming, Neal, & Li, 1999), a special record linkage (Fox, Stahlsmith, Remington, Tymus, & Hargarten, 1998), or patient interview (Phillips-Howard, Mitchell, & Bradley, 1990).

2.14.2.4 Acceptability

The acceptability of the public health surveillance system is described by the willingness to participate in the surveillance system by institutions and persons that operate the system, as well as those that use the data (CDC, 2001). For quantitative measurement of acceptability, completeness of surveillance forms may be assessed, physician, laboratory, or health facility reporting rate may be computed, and timeliness of data reporting can be analysed (CDC, 2001).

2.14.2.5 Sensitivity

The sensitivity of a public health surveillance system can be described as the proportion of the cases of the disease that is detected by the surveillance system. To be able to measure the sensitivity of the surveillance system, data has to be collected or one should have access to data that is collected by another surveillance system. This will lead to the establishment of the true frequency of the condition in the population under surveillance (Sekar & Deming, 1949) coupled with validation of the data collected by the system. Data sources that may be used to assess the sensitivity of the public health surveillance system include medical records (Johnson et al., 1997; M. L. Watkins et al., 1996) and registries (Payne et al., 1995; Van Tuinen & Crosby, 1998). Sensitivity could be assessed for the system's data variables, for each data source, or for combinations of data sources (M. L. Watkins et al., 1996).

2.14.2.6 Positive predictive value

The proportion of reported cases that actually have the health related event under surveillance is referred to as PPV (Weinstein & Fineberg, 1980). The PPV reflects the sensitivity and specificity of the case definition; for example, the screening and diagnostic tests for the health related event and the prevalence of the health related event in the population under surveillance (CDC, 2001). In assessing PPV, primary emphasis is placed on the confirmation of cases reported through the surveillance system. Positive predictive value may be calculated through a record of the number of case investigations completed and the proportion of reported persons who actually had the health related event under surveillance (CDC, 2001).

2.14.2.7 Representativeness

The degree to which the surveillance system reflects the actual distribution of the health condition in the population is referred to as representativeness. However, special studies are usually conducted to examine representativeness (CDC, 2001) .

2.14.2.8 Timeliness

The speed between steps in a public health surveillance system reflects timeliness. The interval usually considered first is the amount of time between the onset of a health related event and the reporting of that event to the public health authority that is mandated to implement control and prevention measures (CDC, 2001). The timeliness of a public health surveillance system should be evaluated in terms of availability of information for control of a health-related event, including immediate control efforts, prevention of continued exposure, or programme planning (CDC, 2001).

2.14.2.9 Stability

The ability to collect, manage, and provide data properly without failure and to be operational when needed is referred to as the stability of the public health surveillance system (CDC, 2001). The system's stability can be measured by the number of unscheduled outages and down times for the system's computer, the costs involved with any repair of the system's computer, the percentage of time the system is operating fully, the desired and actual amount of time required for the system to collect or receive, manage, and release the data (CDC, 2001).

2.15 Reviewing TB and HIV/ART policy guidelines in South Africa

The AGREE II tool is a widely used instrument for the appraisal of guidelines (Brouwers, Kerkvliet, Spithoff, & Consortium, 2016; Siebenhofer et al., 2016) and has been endorsed by the WHO (2012) and South African researchers (Kredo et al., 2012; Wiseman et al., 2014). Furthermore, its use has also been demonstrated in other literature (Beckett et al., 2019; Eikermann, Holzmann, Siering, & Rüther, 2014; Grimmer et al., 2016; Sabharwal et al., 2013; Sharma et al., 2017; Vlayen, Aertgeerts, Hannes, Sermeus, & Ramaekers, 2005; Yao et al., 2017).

2.15.1 Search strategy for TB and HIV/ART policy guidelines in South Africa

The strategy to identify suitable guidelines included searching Google, Google Scholar, South African National and Provincial Departments of Health websites, non-government organisation websites, the Medical Literature Analysis and Retrieval System Online

(Medline) via EBSCO and PubMed databases for TB and HIV/ART policy guidelines. Search terms included the following: "Tuberculosis", "Anti-retroviral treatment", "Human Immunodeficiency Virus", "policy" "guidelines" and South Africa as subject headings.

2.16 Summary

In this chapter, the strategy for the literature search was provided to give the reader information on how relevant literature was searched; for example, the use of Medline via EBSCO and PubMed databases and the setting up of alerts in order not to miss any new relevant literature. In addition, it enabled the researcher to acquire knowledge on the various topics that were discussed in this chapter. Furthermore, the literature was used to provide a brief introduction of the clinical manifestation of TB. The history and natural history of TB were presented as well as the epidemiology of TB globally, in sub-Saharan Africa, and South Africa. The epidemiology of TB revealed that the highest TB burden was in the sub-Saharan Africa region with South Africa being among the high TB burden countries. The chapter further demonstrated that HIV is the most potent risk factor for TB although there are other risk factors such as smoking, alcohol, SES, nutrition, and type of occupation.

The chapter also discussed the South African National TB programme. The evaluation of the surveillance system was highlighted with further discussion of the Updated Guidelines for Evaluating Public Health Surveillance Systems. In addition, the chapter provided a detailed description of the attributes of the public health surveillance system. This is important to this study in particular because of the focus on surveillance of TB in South Africa and the use of the Updated CDC Guidelines. Furthermore, the chapter introduced the AGREE II tool together with the search strategy for the policy guidelines. The next chapter describes the research methods with detailed information about the data sources and analysis methods applied in the study.

Chapter Three - Research Methods

3.0 Introduction

The previous chapter provided information about what is currently known regarding the epidemiology of TB at a global level, the sub-Saharan region, as well as in South Africa. In this chapter, the methods that were applied in conducting the research are discussed. The chapter begins by considering the epistemological approach to the research and providing details of the study design. A detailed account of the process for acquiring the data sets is discussed, including the data sources (National Department of Health TB surveillance data and the TB mortality data) used for this research. Next, the various methods of analysis are described: the evaluation of the TB surveillance system using the updated CDC guidelines, a descriptive epidemiological and inferential analysis, the geospatial analysis, concordance between ART and TB mortality, and the policy document analysis. Finally, a chapter summary will be presented.

3.1 Epistemology

This is a quantitative dominant mixed methods research guided by a positivist perspective; the aim of which is to uncover the direct causes of particular outcomes. A positivist perspective primarily uses empirical data to prove or disprove a theory. It optimally measures the clinical impact of a disease (Creswell, 2003); for example, mortality due to TB, as is the case for this research. The positivist researcher maintains that there is a possibility of being neutral and non-interactive in managing the research (Morris, 2006), thereby enabling the researcher to become an objective analyst, making unbiased analyses of the collected data. This makes the positivist perspective appropriate for research which utilised secondary health data and policy guideline documents from different sources. Use of these types of data overcome any ambiguity in meaning that may arise as a result of misinterpretation, as may be the case in semi structured interviews. Positivists prefer an analytical interpretation of quantifiable empirical data (Druckman, 2005). Surveillance and policy guideline document reviews are open to interpretation but, within the confines of the funding, the researcher was limited to applying existing frameworks.

3.2 Ethical approval

The study obtained ethical approval from both the Auckland University of Technology Ethics Committee (AUTEC) (see Appendix A) and the South African Medical Research Council

ethics committee (see Appendix A). The process of obtaining ethical approval in South Africa required a scientific review of the research protocol by scientists in South Africa that were selected by the South African Medical Research Council. In addition, the ethics committee required commitment from the Department of Health, Statistics South Africa, and the National Health Laboratory that the researcher was going to be granted access to the TB databases. To fulfil this requirement, the researcher acquired commitment from the three departments to provide the TB data. Because the research could not be completed in one year, the researcher requested for an extension of the ethics approval from South Africa (see Appendix A)

Ethical considerations for this PhD research included respect for privacy and confidentiality of participants whose records were accessed in the TB databases. The researcher understood the importance of privacy and confidentiality as he had previously worked as a Deputy Director responsible for data management at the South African National Department of Health, as well as being a Director responsible for Health Statistics at Statistics South Africa in the Republic of South Africa. To protect the identity of participants, TB data with personal identifiers were stored in a password protected external hard drive that could only be accessed by the researcher.

3.3 Design of the study

This study is a quantitative dominant mixed methods one. The researcher first conducted a secondary data analysis (epidemiological and geospatial) of TB databases, followed by a TB and HIV/ART policy guideline review. The use of mixed methods has become popular as a suitable method in applied research (Creswell, 2014). Mixed methods involves multiple methods from the two main methods i.e., quantitative, and qualitative. Mixed methods came up as a result of a desire of researchers who believed that both quantitative and qualitative methods are useful when applied together in addressing research questions (Creswell, 2014). The use of mixed method does not only involve a combination of the two main research methods in one study but can include the use of different data types and methods of analysis in one study as was the case for this study. In the following sections, the secondary TB data analysis and policy guideline document review are described.

3.4 Data sources

As well as secondary health data, the researcher acquired the 2011 population census from South Africa. The data sources used were: the national TB ETR from the National Department of Health and mortality data from the civil registration system that is managed by Statistics South Africa (a Government department mandated to produce official statistics). Initially

contacts for data acquisition were established with the relevant departments (Department of Health, Statistics South Africa, and the National Health Laboratory).

3.5 Research method

The researcher started the analysis with an evaluation of South Africa's TB surveillance and mortality data from 2005-2015, and then conducted a descriptive epidemiological and inferential analysis. Furthermore, geospatial analysis was conducted on the TB ETR and civil registration data for 2005 and 2010. The researcher finally conducted a policy guideline document review for the period 2004-2016.

The researcher conducted the epidemiological analysis of TB data using the following software: SAS version 9.4m6 and the Statistical Package for Social Scientists (SPSS) version 26. The primary statistical package was SAS; SPSS was utilised for some of its special features (i.e., cross checking the SAS outputs). Microsoft Excel (MS Excel) was used, especially for the construction of graphs.

3.5.1 Access to the TB data sets

This details what the researcher followed to access and acquire the TB data sets and the challenges encountered. The data sets themselves are discussed in the next section. The researcher made contact with the identified individuals of the three departments and arranged dates to travel to South Africa from New Zealand to meet with them and discuss the process of acquiring access to the data. The researcher had meetings with the officials responsible for TB mortality data within Statistics South Africa, and another meeting was held with the official in charge of the TB centre for the National Institute of Communicable Diseases (NICD). In addition, another meeting was held with the official in the SAMRC who was working directly with the TB officials of   the Department of Health. After all these meetings, the researcher was assured that approval to access the TB data would be granted after a formal request (see Appendix C) and signing a data user's agreement (see Appendix D) for Statistics South Africa and the Department of Health. The NICD was to draft a user's agreement and get it approved by their Legal Department. The National Department of Health and Statistics South Africa granted access to the TB data; however, due to privacy issues, the NICD was unable to provide access to the laboratory TB surveillance data. In the next section, the researcher discusses the data sets.

3.5.1.1 Census (demographic data)

Since becoming democratic, South Africa conducts a population census every 10 years, with the most recent being the 2011 census. The South African census counts those that are resident on the census night. The 2011 census collected data at both an individual and household level. The data collected for individuals were; sex or gender, age, population group (race), geographic location (municipality), educational level (no schooling to highest level-Masters/PhD), employment status (worked for a wage, run or did any kind of business, and help without being paid). Data collected at household level comprised, housing (type of living quarters, type of main dwelling, construction material, number of rooms, water supply, and toilet facilities) agricultural activities, household goods and services (ownership of livestock, refrigerator, stove, vacuum cleaner, telephone, and access to internet).

The objective of conducting a census is to enumerate everyone it is intended to count, failure of which leads to an undercount (D. Martin, 2010). Due to high undercounting, South African censuses have become subject to controversy; particularly since 1996 when the first census after attainment of democracy was conducted. An undercount could have a major impact on this research by overestimating some of the indicators like the prevalence of TB. The 2011 census had an undercount of 14.6% (Gumbo & Odimegwu, 2015). The undercount was identified in provinces, population groups, sex or gender, and age groups. Western Cape province had the highest undercount of 17.8% with Free State province having the least of 9.3%. The white population group had the highest undercount of 15.6% while the black African had the least of 9.9%. For sex or gender, males (15.9%) had a higher undercount than females (13.4%). The 20-29 year age group had the highest undercount of 18.1% with the over 65 years old having the least of 9.8% (Statistics South Africa, 2012). Achieving 100% accuracy in census enumeration is often difficult, mainly due to undercounting; therefore, adjustments are often done for correction. This research, therefore, used the adjusted figures. Census data were available from Statistics South Africa's website (Gumbo & Odimegwu, 2015).

For this research, census data were used to compute proportions of TB notifications and deaths at lower levels than the national level. In addition to the census, Statistics South Africa produces official half year population estimates annually. These were acquired and used as the denominator for analysis for the specific years determined in the study.

3.5.1.1.1 Limitations of census data and population estimates

Arguably population estimates based on census data may not give an accurate reflection of population trends in a country. Populations and settlement patterns tend to change, sometimes

more rapidly, in between census times, meaning projections from previous census may not reflect actual trends in the years ahead.

3.5.1.2 National TB ETR (surveillance data)

The ETR is maintained by the national Department of Health with the purpose of registering and tracking the progress of individuals initiated on treatment for TB. The ETR defines a TB case as those that are either symptomatic suspected cases or laboratory confirmed cases (Podewils et al., 2015). For this study, the ETR had more than 3 million patient records. Individual information is captured on the blue card (Patient Clinic/Hospital card, see Appendix B), a source document or tool for the ETR, and includes: name, surname, date of birth, age, identity number (ID), gender, race, health district, clinic or hospital, home address, patient category, sputum results and basic information on HIV status, (whether positive, negative, unknown, and date last test was taken) and HIV related treatment data (on cotrimoxazole or ART) among TB patients.

A number of reports can be generated from the ETR for a specified period or as a summary over time and include: reports on TB patients registered and reports on treatment outcome (Department of Health, 2014).

3.5.1.3 Civil registration system (Mortality data)

The mortality data define a TB case as all those deaths where TB was captured as a primary or secondary cause of death. In South Africa, national mortality statistics are captured in the civil registration (CR) system. In recent years, the country has adopted the Africa Programme on Accelerated Improvement of Civil Registration and Vital Statistics (APAI-CRVS) (Kabudula et al., 2014). The CR data are captured by Statistics South Africa from death notification forms (Form BI-1663, see Appendix E) that are submitted to the Department of Home Affairs offices for death registration as a requirement by the country's Births and Deaths Registration Act No 51 of 1992 (Republic of South Africa, 2010). Since 2005, the CR system has captured over 500 000 deaths annually with TB being the leading cause of death since 2013 (Statistics South Africa, 2015). For this study, the TB mortality data had more than 700 000 TB deaths.

The information collected includes personal characteristics of the deceased and details on causes of death. Anonymised causes of death data are available from Statistics South Africa's website; however, a special request is required for data with the deceased's details which include: name and surname; sex or gender; day, month, year of death; cause of death; underlying cause of death; day, month, year of birth; institution or place of death, and village

name. Statistics South Africa also provides the data user with metadata that contain variable names and their description. For this study, the most appropriate metadata was for the period 1997-2015.

3.5.2 Eligibility criteria

The sample for this research was all the TB cases and TB deaths in either of the two data sets. All TB cases and TB deaths captured in the data sets for the period 2005-2015, that were not duplicates, were eligible for the study. The TB cases were defined earlier under each of the data sources.

3.5.3 Data collection and analysis

After permission was granted by each department—National Department of Health and Statistics South Africa—to access the data sources with personal identifiers the researcher travelled to South Africa to personally collect data from the designated officials. The TB data were put on a secure memory stick which was password protected before the researcher returned to New Zealand.

The first step in analysis was to remove duplicate cases from both the ETR and mortality data. Duplicate cases for the ETR were identified as those that had the same gender, date of birth, age in years, district, province, and name or surname where available. In addition, for the mortality data duplicate cases included date of death.

3.6 Method of evaluation of the TB surveillance system using the updated CDC guidelines

Sections of the updated CDC guidelines that provide a framework for evaluating surveillance systems were applied for the evaluation of specific parts of the TB surveillance system. The attributes that were evaluated for this research were data quality, timeliness, and concordance between TB data in the ETR and the civil registration system. The variables that were available in the data sets could be used to investigate only these three attributes.

The quality of the data recorded in the public health surveillance system is reflected through completeness and validity of the data. Data quality may be assessed through the percentage of missing variables (CDC, 2001) which, for this research, was done by analysing the missing variables that are supposed to have been captured in the ETR and mortality data. For the ETR, the variables were: surnames, names, age, date of birth, province, district, sub district, gender, started on treatment, treatment outcome, patient category, HIV status, and clinical manifestation. The variables for the mortality data were: gender, date of birth, age in years,

death date, marital status, population group, province, district, sub district or local municipality, level of education, occupation, industry, smoking status, method of ascertainment of death, and place or institution of death.

3.6.1 Timeliness

Timeliness of a public health surveillance system is reflected by the amount of time taken between the various steps in the surveillance system. The interval usually considered first is the amount of time between the onset of a health related event and the reporting of that event to the public health authority that is mandated to implement control and prevention measures (CDC, 2001). For this study, timeliness of the surveillance system could only be measured within Western Cape province because the variables that could be used were only available in the TB data set for 2013-2015 which was only for Western Cape province.

One of the indicators for the South African TB programme is the time to treatment initiation, which is defined as the time taken from specimen collection to starting the patient on TB treatment (Department of Health, 2014). Timeliness of the smear collection is important because it can give an indication of how long it takes to get a diagnosis; moreover, early diagnosis and the immediate initiation of TB treatment are essential for an effective TB control programme. Below is the formula that was used to compute timeliness in hours.

Timeliness = 24 (date of smear collection – date of start of treatment).

3.6.2 Positive predictive value (Concordance)

The PPV reflects the sensitivity and specificity of the case definition; for example, the screening and diagnostic tests for the health related event and the prevalence of the health related event in the population under surveillance. PPV may be calculated through a record of the number of case investigations completed and the proportion of reported persons who actually had the health related event under surveillance (CDC, 2001) (see Table 3.1). Because the researcher did not get access to the laboratory TB data, it was not possible to calculate the PPV. Instead, a summary of TB deaths in the surveillance system were compared with those of the TB deaths from the civil registration system for concordance.

The formula used to calculate the concordance is:

Number of TB deaths in the civil registration system – Number of TB deaths in the ETR x 100.

Number of TB deaths in the civil registration system

Table 3.1: *Calculating Sensitivity and Positive Predictive Value**

	Mortality data		Total
ETR	**Positive**	**Negative**	
Positive	True positive (A)	False positive (B)	**A+B**
Negative	False negative (C)	True Negative (D)	**C+D**
Total	**A+C**	**B+D**	**A+B+C+D**

Sensitivity = A/(A +C); PPV = A/(A + B) * These formulae were not the ones used

3.7 Descriptive epidemiological analysis

A descriptive epidemiological analysis of TB surveillance and mortality TB data from the ETR and CR respectively for all reported cases and deaths of TB from 2005-2015 was conducted. As a result of epidemiological analysis, standardised indicators such as TB notification rates (prevalence rates), distribution by age, gender, proportions, and percent changes in prevalence rates of TB cases for each year under review were estimated.

The epidemiological measure used was TB notification rates (prevalence), which is defined as the number of current cases in a defined population at a specified point in time (Bonita et al., 2006). For this study, prevalence was appropriate because it provided details of the number of TB cases for a range of variables over the period of study. The prevalence was computed using the total number of TB cases for the year divided by the total population for that municipality for that year. Statistical comparisons were made across provinces, district municipalities, gender, and age. These variables were selected because they were deemed appropriate in describing the epidemiology of TB by time, place, and person which is a crucial component of epidemiology. Data were analysed and expressed as number of TB cases or deaths per 100,000 population. The method used for the calculation of TB death rates will be detailed in the subsections after the TB notification rates. Proportions of cases of the different sub-population groups in South Africa was calculated for the period under study.

Tuberculosis data were analysed by race or ethnicity, and age groups. The significance of this analysis was to show the trend of cases among the different age groups and most at risk sub-population groups. The following subsections detail the methods used to compute the various indicators for this study.

3.7.1 TB notifications by place

Notification rates for the period under study were calculated by dividing the total number of TB cases notified in each year for either South Africa or the province or district or health sub

district by the midyear population estimates for either South Africa or the province or district or health sub district, and then multiplying the figure by 100 000 with a 95% confidence interval.

3.7.2 TB notifications by gender and age

Analysis was done using age and gender variables as the numerator and gender and age group specific midyear population estimates for South Africa as the denominator. This was then multiplied by 100 000 with a 95% confidence interval.

3.7.3 TB notifications by type of infection

In order to analyse TB notifications by type of infection, the disease category variable from the TB data set was used. The two main categories were pulmonary TB and extra pulmonary TB. Analysis of either pulmonary TB or extra pulmonary TB notification rates was done for each year of the study period. Proportions were calculated for either pulmonary TB or extra pulmonary TB each year by dividing the number notified by the midyear population estimates for that year then multiplied by 100 000.

3.7.4 TB treatment outcome

The variable TB treatment outcome in the TB data set had six categories: completed, cured, defaulted, died, failed, and not evaluated. As discussed earlier, a defaulted TB patient is one who completed at least one month of treatment and returns after interrupting treatment for two months or more. A failed treatment outcome is a patient who received treatment and remained or became smear or culture positive at the end of the treatment period (Department of Health, 2014). For the period under study, proportions of TB cases that completed treatment, were cured after treatment, died during treatment, whose treatment failed or was not evaluated were calculated for each year. The calculations were done by dividing the specific treatment outcome with the number of TB cases for that year, multiplied by 100.

3.7.5 Analysis of TB deaths from the TB mortality data

Analysis of TB deaths by place, person, and time for the period 2005-2015 was also performed. Additionally, analysis was done for the occupation and education of the deceased, the institution of death, and the method of ascertainment of the death. This sub section details the method of analysis of the TB deaths for each one of these variables.

3.7.5.1 Proportion and death rates for TB deaths by place

Trends for proportions of TB deaths as well as TB death rates were analysed by South Africa (national level), provinces, districts, and local municipality for each year of the study period. For the proportions, calculations were done by dividing the number of TB deaths by area or

place; for example, South Africa for a particular year by the total number of TB deaths and then multiplied by 100. Tuberculosis death rates were computed by dividing the total number of TB deaths for that particular area by the midyear population estimates for that area and multiplied by 100 000.

3.7.5.2 Proportion and death rates for TB deaths by age and gender

Analysis for trends of proportion TB deaths and TB death rates was performed for the period 2005-2015. The proportion was calculated by dividing the total number of TB deaths, either males or females in a particular age group, by the total number of TB deaths. Whereas the age and gender specific TB death rates were calculated by dividing the TB deaths in either age group or a given gender by the age group or gender specific midyear population estimates, respectively. This was then multiplied by 100 000.

3.7.5.3 Proportion and death rates for TB deaths by population group

Analysis was done using the population groups (race) variable which in South Africa is classified into four categories; black African, White, Coloured, and Indian or Asian. The proportion in each population group classification was calculated by dividing the total number of TB deaths in a particular population group by the total number of TB deaths for the study period. Cumulative TB death rates for each population group were calculated by dividing the total number of TB deaths in a specified population group by the cumulative midyear population estimates for the study period. The result was then multiplied by 100 000.

3.7.5.4 Proportion of TB deaths by level of education

The TB mortality data set has a variable for level of education attained by the deceased. There are 14 levels of education in South Africa ranging from Grade R to University. Analysis was done to find the distribution of the proportion of TB deaths among the different levels of education. Calculation was done by dividing the total number of TB deaths per education level with the total number of TB deaths for the study period. This was then multiplied by 100 in order to get the proportion.

3.7.5.5 Proportion of TB deaths by occupation group and industry

Analysis of the TB mortality data was done to establish the proportions of TB deaths in the different occupation groups and the type of industry the diseased was working in. Both the occupation group and the industry were classified into 10 categories. Proportions of TB deaths in each category were calculated as the total number of TB deaths in that category divided by the total number of TB deaths for the period 2005-2015, multiplied by 100.

3.7.5.6 Proportion of TB deaths by smoking status

TB mortality data were analysed to compute the proportion of TB deaths between smokers and non smokers for the period 2005-2015. Proportions for either smokers or non smokers were computed by dividing the total number of smokers or non smokers with the total number of TB deaths for the period under study, multiplied by 100.

3.7.5.7 Proportion of TB deaths by method of ascertainment of the cause of death

The mortality TB data set captures information on how the cause of death was ascertained. This variable has 10 major categories. Analysis was performed on the TB death data for the period 2005-2015 to establish proportions of TB deaths in the different categories of ascertainment of TB deaths. A proportion for each of the category was calculated by dividing the total number of TB deaths in that category with the total number of TB deaths for the study period, multiplied by 100.

3.7.5.8 Proportion of TB deaths by place or institution of death

Information on where the TB death occurred is captured in the TB mortality data under five major categories; with an additional three categories of unspecified, unknown, and other. For this study, proportions in the different categories were analysed to ascertain the distribution of where TB deaths occurred during the period 2005-2015. Proportions for each category were calculated by dividing the total number of TB deaths in each category of place or institution of death with the total number of TB deaths within the study period, multiplied by 100.

The epidemiological analysis of the TB data was followed by geospatial analysis. The details follow in the next section.

3.8 Geospatial analysis

In South Africa, the NTP operates at five levels of intervention: national, provincial, district, sub district, and facility (Podewils et al., 2015). The district level is the lowest level tasked with the implementation of policies. Strategies to prevent and manage diseases, for example TB, require knowledge and understanding of the people concerned, communities, and environmental circumstances (Bagheri et al., 2015). This study investigated district municipality level (where health facilities and district offices are located), spatial patterns (spatial autocorrelation and any hot spots) of TB cases, and TB deaths in South Africa for 2005 and 2010. Tuberculosis data were analysed to identify which district municipalities had the highest and lowest rates of TB cases and deaths for the period 2005 and 2010.

Analysing health data usually involves statistical, demographic, or epidemiological methods. However, epidemiologists are now gradually applying spatial epidemiological analysis as part of health research when they are planning health policies and making evidence based decisions (Sherman et al., 2014). Spatial and spatiotemporal analyses have been in use for over 40 years. In recent times, there has been an emergence of new approaches, with the GIS being one of them (Nunes, 2007). The GIS can be used to characterise space and time distribution of TB cases and deaths with a generation of colour maps to depict the distribution of TB case notification rates and death rates for each district municipality in South Africa.

A number of spatial analysis methods are able to test for the presence of global heterogeneity (presence of a different value for the characteristic of interest in the population under study), due to their capacity for spatial autocorrelation or space time interaction. Spatial analysis of TB cases from the ETR and TB deaths from the CR was conducted for this study. The presence of spatial auto-correlation, as well as space time clusters of TB cases and deaths with the identification of their possible locations, was determined with spatial auto-correlation using both the Global and Local Moran's Indices methods (Moran's I). The Global Moran's I is a method widely applied in the measurement of spatial autocorrelation. Moran's I has the ability to establish the level of similarity between values of each selected variable in a district municipality to the values of this variable in any neighbouring district municipality. Moran's I is used more widely than any other method (Cliff & Ord, 1970; Kumari, Sarma, & Sharma, 2019; Lee & Li, 2017). Moran's I statistic for spatial autocorrelation is expressed as (Anselin, 2020):

$$I = \frac{\sum_i \sum_j \omega_{ij} z_i z_j / S_0}{\sum_i z^2_i / n}$$

where z_i is the deviation of an attribute for featuring i from its mean ($x_i - \overline{x}$), $\omega_{i,j}$ is the elements of spatial weight matrix, $S_0 = \sum_i \sum_j \omega_{ij} z_i$ is the sum of all weights and n is the total number of observations.

The values of Moran's I range from -1 to +1 (Getis & Ord, 1992). Moran's I values of around +1.0 indicate clustering, while values of around −1.0 indicate dispersion. Therefore, if the index is closer to +1, there is a high level of similarity between the district municipality and any neighbouring district municipality for TB cases or deaths; if it is closer to -1, then they are dissimilar; and if it is zero, there is spatial independence (Getis & Ord, 1992). Spatial

dependence indicates that there is a high level of similarity between a district municipality and any neighbouring district municipality with regard to the TB cases or deaths. This means that those district municipalities with high number of TB cases or deaths are located near those with high numbers and those with low numbers are located near those with low numbers.

The Local Moran's I was applied in this study to explain the kind of spatial correlation that may have occurred in the distribution of TB cases and deaths among the district municipalities in South Africa. The results of the Local Moran's I classify district municipalities into high-high clusters, meaning high TB cases or deaths are located next to high TB cases or deaths; and low-low which means that low TB cases or deaths are neighbouring to low TB cases or deaths (cold spots). Then there are spatial outliers; for example, high-low clusters which means that there are high TB cases or deaths amongst low TB cases or deaths or low-high clusters which means low TB cases or deaths among high TB cases or deaths in the district municipalities (Getis & Ord, 2010).

Hot spot analysis is a method applied to establish the presence of either hot spots or cold spots in an area. Its use is mainly the identification of local "pockets" of dependence (Getis & Ord, 2010) which identifies if there is similarity in the values of each selected variable in a district municipality to the values of this variable in any district municipality located next to it. For this study, the local Getis-Ord G was used for hot spot analysis. A hot spot in a district municipality was defined as an area where an elevated number of TB cases or deaths occurred while a cold spot as an area where a low number of TB cases or deaths occurred. Additionally, the local Getis-Ord G (hot spot) analysis is used to identify local "pockets" of dependence where the Moran's I is unable to do so (Getis & Ord, 1992). Furthermore, the local Getis-Ord G (hot spot) analysis generates Z scores and P values. For a significant hot spot, the Z score is high and the P value is small for the variable under study, whereas a low negative Z score and a small P value are indicative of the presence of a significant cold spot. The higher (or lower) the Z score, indicates intensity of the clustering. For a Z score near zero it indicates an absence of spatial clustering (Getis & Ord, 1992).

For this study, spatial analysis was done for TB cases and deaths for two data points (2005 and 2010). This was mainly because the most recent census was conducted in 2011 and it is these census population figures that were used as a standard population. Furthermore, the analysis was done using crude TB notification and death rates, followed by age-sex standardised TB notifications and TB death rates. Standardisation was done to enable comparison of TB

notification and TB death rates for groups of the populations of 2005 and 2010 that may have different age structures. Standardisation is recommended where there is a need to remove those effects that may arise as a result of a variation in the age composition of the population under study (Ahmad et al., 2001). For this research, the direct standardisation method was used to compute the age-sex standardised TB notification and death rates per 100 000 for each district municipality in South Africa using the census 2011 age distribution as the standard. Spatial analysis was performed using the Geographic Data Analysis (GeoDa) version 1.14 software. A South African shape file with all the district municipalities was imported into the GeoDa software so that geo spatial data could be created. All variables for the study were first imported from the SAS files into MS Excel and prepared to compute age sex standardised rates which were then merged into the South African shape file. The spatial analysis generated maps at a district municipality level for the overall, male and female crude TB notification and death rates and then followed by the overall, male and female age sex standardised TB notification and death rates for 2005 and 2010 data points. In addition to the TB notification and death rates, the South African Multidimensional Poverty Index (SAMPI) was mapped for the years that SAMPI data was available (2001 and 2011). The aim was to observe if there were any relations between TB notifications and deaths with poverty; for example, if district municipalities with hotspots coincided with those with high SAMPI. Furthermore, HIV prevalence for 2010 was mapped to investigate if there was an association between TB notifications, deaths, and HIV. The HIV prevalence data for district municipalities were not available for 2005; therefore, the study mapped only 2010 data.

3.8.1 Spatial dependency analysis

To identify a potential association in the observed spatial variations of TB notifications and deaths (dependent variable), in instances where there were hot spot clusters of district municipalities, the researcher conducted a regression analysis using the spatial lag regression analysis for the 2010 data. The independent variables were the SAMPI and HIV. Below is the formula for the spatial lag analysis (Anselin & Griffith, 1988).

$$Y = p W_1 Y + X\beta + \mu,$$

$\mu = \lambda W_2 \mu + \varepsilon$ where $\varepsilon \sim MVN\ (0, \sigma^2 I_n)$, where Y, the dependent variable, is a (n x1) vector of the natural logarithm of TB notifications and deaths in the district municipalities in the year under study; X is a (n x k) matrix of k explanatory variables; p and λ are spatial auto regressive coefficients; W_1 and W_2 are (n x n) spatial weight matrices, μ is the unobserved

error term which is likely to incorporate spatial correlation through its first term, ε is a (n x 1) vector of unobserved terms, with an identical and independent distribution. The MVN is the multivariate normal distribution, while I_n is the (n × n) identity matrix. For spatial lag, the spatial weight matrix of the error term (W_2) in the formula is equal to zero (Anselin & Griffith, 1988). The researcher performed the analysis using the GeoDa software version 1.14.

3.9 Concordance between ARV and TB

To investigate concordance, plots of TB mortality, TB notifications, TB/HIV co-infection notifications, and ART uptake were undertaken. Analysis was undertaken to identify or examine correlations and time lag effects between ART uptake, TB related mortality, TB notifications, and TB/HIV co-infection notifications. Analysis aimed to investigate whether an observed variation in the outcome (TB notifications or deaths) could be explained by changes in the main exposure (ART uptake). One of the core indicators of the South African National Strategic plan for HIV and TB 2011-2016, is the percentage of deaths due to TB and HIV (Department of Health, 2011). For this phase of the study, TB mortality data were analysed at a national level and expressed as number of deaths per 100 000 population. In addition, TB notifications, TB deaths from the ETR, and TB/HIV notifications were analysed at a national level. The ART data accessed from the Department of Health were analysed and expressed as ART coverage. The ART coverage was computed by using the number of people that were on ART as a numerator and the denominator (people living with HIV) as the estimated HIV-infected population from national projections obtained from the Joint United Nations Programme on HIV/AIDS Estimation and Projection Package and Spectrum software. However, these projections do not have figures below the national level; therefore, analysis was limited to a national level.

To examine the association between ART and HIV infection with TB, rates of TB deaths, TB notifications rates, proportion of TB/HIV notifications, and ART were plotted against time for the period under study.

3.10 Method for reviewing TB and HIV/ART policy guidelines in South Africa (2004-2016)

To date, as revealed by the literature search, there was no evidence that there has ever been a study undertaken to review the quality of TB and HIV/ART policy guidelines in South Africa. The quality of guidelines is important because guidelines translate policy into practice (Kredo et al., 2012), they are used to inform decision making, and can lead to improvement in health

care (Hoffmann-Eßer et al., 2017). Therefore, the researcher undertook a review of TB and HIV/ART policy guidelines in South Africa to evaluate their quality (and whether or not they can be recommended to be used by health workers). It is important that TB and HIV/ART policy guidelines are of high quality and that outcomes can be measured. For this PhD, the HIV/ART policy guidelines as well as TB guidelines were reviewed because the management of HIV is crucial in the control of TB. Policy guidelines were reviewed for the period between 2004 and 2016 inclusive, as this was the same time period for the TB data sets.

In order for the researcher to make a decision on which method to use to review the HIV/ART policy guidelines, he consulted with other researchers at universities in New Zealand and Australia, as well as reviewing available literature. Through this process, the researcher identified the Appraisal of Guidelines for Research and Evaluation (AGREE) II tool as an appropriate instrument. The inclusion criteria was for only those TB and HIV/ART policy guidelines in English that were published between 2004 and 2016 and were for South Africa, either at a provincial or national level, or published by non-governmental organisations (NGOs). The study period was chosen so that a comparison between extracted recommendations and data from the ETR for the period 2004-2015 could be performed. For instance, to be able to establish if the data elements that are recommended by the guidelines are the ones that are captured for all the TB records in the ETR for the period 2004-2015. For inclusion of NGOs TB and HIV/ART policy guidelines, the NGO had to have a high revenue in terms of funding (minimum of R 100 000 000.00) as identified from their financial status posted on their website. This inclusion criterion was important because the bigger the NGO, the more likely its activities will have an impact on TB and HIV control in South Africa. The researcher then searched for the TB and HIV/ART policy guidelines online, followed by email contact with the identified non-governmental organisations that did not have any TB and HIV/ART policy guidelines on their websites requesting them to forward these to the researcher. If no response was received within a week after sending the email, the researcher followed up with another two emails.

3.10.1 The AGREE II tool

The AGREE II tool was selected for this research, although its use suggests that the appraiser has to be skilled (appropriate knowledge for the topic and scope of the guideline) and it is time intensive (Siebenhofer et al., 2016) due to the large number of items and criteria that the AGREE II tool recommends to use for the guideline review process. To acquire the necessary skill to use the AGREE II tool, the researcher trained using the AGREE II tool manuals that

are available on the AGREE II tool website. The AGREE II tool was also selected because it has been tested for its reliability (Brouwers, Kho, et al., 2010a) and validity (Brouwers, Kho, et al., 2010b). Reliability is whether the AGREE II tool is able to evaluate the strengths and weaknesses of a policy guideline (Siebenhofer et al., 2016); whereas validity for the AGREE II tool is for it to be able to measure what it purported to measure (Brouwers, Kho, Browman, Burgers, Cluzeau, Feder, Fervers, Graham, Grimshaw, et al., 2010). The AGREE II tool has six domains with a total of 23 items. The domains have a varying number of items ranging from two to eight. The six domains for the AGREE II tool are: Scope and purpose, Stakeholder involvement, Rigour of development, Clarity of presentation, Applicability, and Editorial independence. Table 3.2 depicts the AGREE II tool domains and associated items.

Table 3.2 *AGREE II Instrument (AGREE Next Steps Consortium, 2017)*

Domain	Item
Scope and purpose	There are three items in this domain and their purpose is to determine whether the overall objective, health question, and target population are described.
Stakeholder involvement	This domain has three items that evaluate to what extent the various relevant (an appropriate match to the topic or scope of the guideline) professionals or stakeholders were involved in developing the guidelines.
Rigour of development	This domain has eight items (the highest number for all the domains). The items focus on methods of how evidence was gathered and synthesised, as well as evidence of any process that is available for updating the guidelines.
Clarity of presentation	There are three items in this domain that deal with the clarity of language used, how the guideline is structured, and its format.
Applicability	This domain has four items. The items evaluate the process of guideline implementation specifically considering any barriers or enablers, especially as regards to the required resources.
Editorial independence	This domain has two items. These items focus on whether there is any bias in guideline development towards the interests of those involved.

In addition to the six domains, there is an overall guideline assessment that rates the overall quality of the guideline and whether the guideline would be recommended for use. Domains are scored so that the AGREE II tool is able to identify strengths, limitations, and quality of guidelines. To get a domain score, each item is scored on a scale ranging from one (strongly

disagree) to seven (strongly agree). The same scoring criteria are applied to the overall guideline assessment. In addition to the scoring criteria, scoring of items requires a level of judgement from the reviewer (AGREE Next Steps Consortium, 2017).

The domain scores were calculated as follows:

$$\frac{\text{Obtained score} - \text{minimum possible score x 100}}{\text{Maximum possible score} - \text{minimum possible score}}$$

Where maximum possible score = seven (strongly agree) x number of items in the domain and minimum possible score = one (strongly disagree) x number of items in the domain (AGREE Next Steps Consortium, 2017) .

The AGREE II tool does not prescribe minimum domain scores for either high or poor quality guidelines; rather, it suggests the reviewers make that decision. For this research, high quality guidelines were judged as being those with scores of above 70% for each of the domains as suggested by the AGREE II tool (AGREE Next Steps Consortium, 2017); this is slightly higher compared with other studies that have used the AGREE II tool (J. Armstrong, J, Rodrigues, Wasiuta, & MacDermid, 2016; Quintyne & Kavanagh, 2019; Sharma et al., 2017; Yao et al., 2017). A slightly higher score was selected because quality of guidelines is important and good quality leads to an improvement in the quality of health care (Hoffmann-Eßer et al., 2017). The overall quality assessment of the guideline is ranked on a scale, ranging from one (lowest possible quality) to seven (highest possible quality). The overall scoring of the quality assessment is based on the reviewer's judgement, who takes into consideration the appraisal of the items in the domain scores. Then a recommendation is made which will be either to use the guideline as it is (those with an overall score of seven) or for use with modifications (those with an overall score of more than or equal to five but less than seven), or not recommended for use (those with an overall score of less than or equal to four).

In addition to reviewing the quality of the guidelines, for this PhD, recommendations related to data management, monitoring, and evaluation were extracted from the TB and HIV/ART policy guidelines under review. It may be argued that these data management, monitoring, and evaluation recommendations have an impact on the quality of the TB and HIV/ART data; therefore, the extracted recommendations were appraised and summarised and the study investigated to what extent they were implemented by examining if there were gaps (for

example variables with missing records or variables that are missing) in the TB surveillance data from the National Department of Health**.**

3.11 Summary

Chapter Three has outlined the methods that were applied to conduct the research. The use of secondary health data for this study was justified. Details of the methods of analysis were provided. In addition to secondary TB data analysis, the review of the South African TB and HIV/ART policy guidelines was discussed. Review of the HIV/ART policy guidelines was necessary since the management of HIV is a very important component of TB control.

The next chapter presents the results from the evaluation of the TB surveillance system using the updated CDC guidelines, and the epidemiological and inferential analysis of the secondary TB data (ETR and mortality data). The results of the geospatial analysis will be presented in Chapter Five; findings for the concordance of TB and ART uptake in Chapter Six; and finally, findings of the review of the TB and HIV/ART policy guidelines using the AGREE II tool will be presented in Chapter Seven.

Chapter Four - Results: Evaluation of the Tuberculosis Surveillance System and Epidemiological Analysis

4.0 Introduction

The previous chapter provided information on how the TB data were collected and the methods that were applied for the descriptive, inferential, and geospatial statistical analysis of the secondary TB data, and the TB and HIV/ART policy document analysis. This chapter presents the findings from the evaluation of the TB surveillance system and the descriptive epidemiological and inferential analysis of the ETR and mortality TB data. The analysis had two hypotheses: 1) There is a lack of concordance between the two key surveillance databases; and 2) there is geographical variation in TB notification and death rates across South Africa. The ETR data of 3 818 192 cases had 9.0% (343 872 TB duplicate cases) that were identified and excluded from the analysis.

4.1 Evaluation of the TB surveillance system

In this section, results of the evaluation of the TB surveillance system are presented. The section begins with results of the data quality (completeness) for the ETR followed by those of the TB mortality data. These are followed by the timeliness results. Finally, the results of the concordance of TB deaths in the ETR and the civil registration system are presented.

4.1.1 Data quality - Electronic TB register data completeness 2005-2012

The completeness of key variables for the period 2005-2012 is presented in Table 4.1. The majority of variables; namely gender, age in years, province, district, sub district, started on treatment and treatment outcome, had a completeness of 100% for the entire 8-year period. Contrary to the age in years, the date of birth variable presented very low completeness; ranging from 5.1% in 2005 to 66.3% in 2010. The variable for HIV status also presented with low completeness; however, it improved steadily over the entire period from 20.6% in 2005 to 90.6% in 2012. For those on ART, completeness was low where the lowest level of completeness was 0.01% in 2005 and the highest level was less than 20% in 2012. Although the patient category and clinical presentation (pulmonary TB, extra pulmonary TB, and both pulmonary and extra pulmonary TB) variables were above 90%, they exhibited some fluctuations from 99.7% in 2005 and 2006 to 95.8% in 2009.

Table 4.1: *Percentage of Completeness of the Electronic Tuberculosis Register Data for South Africa, by Variable and Years 2005-2012 (n = 3 474 320)*

	2005	2006	2007	2008	2009	2010	2011	2012
Number of TB cases notified	323,175	346,595	403,236	471,043	532,018	464,063	501,671	432,519
Demographics								
Date of birth	5.1%	4.6%	4.5%	30.4%	56.4%	66.3%	60.7%	62.8%
Patient category								
Patient category overall	99.7%	99.7%	99.9%	98.2%	95.8%	95.9%	96.6%	97.1%
Risk factor								
HIV status	20.6%	21.0%	25.3%	48.6%	67.6%	80.3%	88.5%	90.6%
Clinical presentation								
Pulmonary TB, Extra pulmonary TB and Both	99.7%	99.7%	99.9%	98.2%	95.8%	95.9%	96.6%	97.1%
Treatment								
ART (for those reported to be HIV positive) n=1,070,831	0.01%	1.8%	6.2%	14.8%	14.4%	16.6%	19.4%	19.7%

4.1.2 Data quality - Mortality TB data completeness 2005-2015

The completeness of mortality TB data variables for the period 2005-2015 is presented in Table 4.2. These variables originate from the death notification form. The majority of variables; namely gender, date of birth, age in years, death date, province, district, and sub district or local municipality, had a completeness of 100% for the entire 11-year period. The two variables that had a low level of completeness were smoking status and level of education of the deceased. For the period, completeness for smoking status increased steadily from 47.4% in 2005 to 70.8% in 2015; while the deceased's level of education increased only slightly remaining low from 44.6% in 2005 to 53.2% in 2015. Unlike all other variables, method of ascertainment of death is the only variable whose level of completeness decreased over the study period from 99.9% in 2005 to 69.0% in 2015. The level of completeness for population group increased from 76.2% in 2005 to 92.7% in 2015 (see Table 4.2).

4.1.3 Timeliness of the TB surveillance system in Western Cape province

Variables that could be used to measure timeliness for the TB surveillance system in Western Cape province were available for the period 2013-2015. Timeliness was measured for the time between specimen collection and the start of TB treatment. For the study period, 138 121 TB cases were notified. Table 4.3 shows that during the study period, 14.1% (20 028) of the TB cases in Western Cape province were started on TB treatment within 48 hours, which is the recommended time period. Timeliness was unknown for some TB cases, mainly because these TB cases did not have a date on which the specimen was taken. In addition, 27.6% (39 204 TB cases) had a specimen collected after starting treatment.

Table 4.2: *Percentage of Completeness of Tuberculosis Mortality Data for South Africa, by Variable and Years 2005-2015 (n = 777 176)*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of TB deaths	83,893	88,120	87,074	86,474	82,008	76,300	68,446	62,971	56,509	52,668	32,713
Demographics											
Marital status	82.6%	82.1%	81.7%	81.8%	80.9%	82.0%	83.6%	84.4%	84.7%	85.2%	83.7%
Population group or race	76.2%	76.3%	76.4%	76.1%	74.8%	77.1%	86.3%	90.4%	92.1%	92.6%	92.7%
Other variables											
Level of education	44.6%	45.9%	45.7%	46.6%	46.3%	47.3%	52.1%	53.9%	54.2%	55.0%	53.2%
Occupation	1.2%	96.3%	96.4%	96.4%	96.8%	96.6%	97.3%	97.5%	97.6%	97.7%	98.0%
Industry	97.4%	96.3%	96.4%	96.6%	96.8%	96.6%	97.3%	97.5%	97.6%	97.7%	98.0%
Smoking status	47.4%	48.3%	48.9%	48.1%	47.6%	49.8%	58.4%	65.5%	67.7%	70.1%	70.8%
Method of ascertainment of death	99.9%	99.9%	99.9%	99.9%	99.6%	77.8%	76.1%	73.2%	71.5%	70.1%	69.0%
Place or Institution of death	90.1%	89.6%	90.0%	91.1%	91.4%	89.8%	86.3%	86.9%	88.6%	88.9%	89.2%

Table 4.3: *Timeliness of the Tuberculosis Surveillance system in Western Cape province, 2013-2015*

Time taken to start treatment after specimen collection	Number of TB Cases	Percentage of TB Cases
≤ 48 hours	20 028	14.1
> 48hrs	34 942	24.6
Unknown	47 868	33.7
Started treatment before specimen collection	39 204	27.6

4.1.4 Concordance between TB deaths in the ETR and the Civil registration

For this study, concordance was demonstrated by comparing the total number of TB deaths in the ETR to those in the civil registration system for the period 2005-2012 (see Figure 4.4). The civil registration system was assumed to contain all the TB deaths and therefore the gold standard for this study. For the entire study period, the total number of TB deaths in the ETR was lower than the ones recorded in the civil registration system. In fact, in 2006 the civil registration had recorded 61 462 more TB deaths than in the ETR. In total, 61.6% (391 136) of 635 286 TB deaths were in the civil registration system and not recorded in the ETR; therefore, the ETR was only able to identify approximately 39% of TB deaths. The lowest difference in the number of TB deaths between the ETR and civil registration system was in 2011 (34 537). Furthermore, results found that the highest total number of observed TB deaths in the ETR and civil registration system were recorded in different years, in 2009 (38 704) and in 2006 (88 120) in the ETR and civil registration system, respectively. These results confirm the hypothesis that there is a lack of concordance between the two key surveillance databases.

Figure 4.1: *Comparison of Tuberculosis deaths from the Electronic Tuberculosis Register and the Civil registration system, South Africa, 2005-2012*
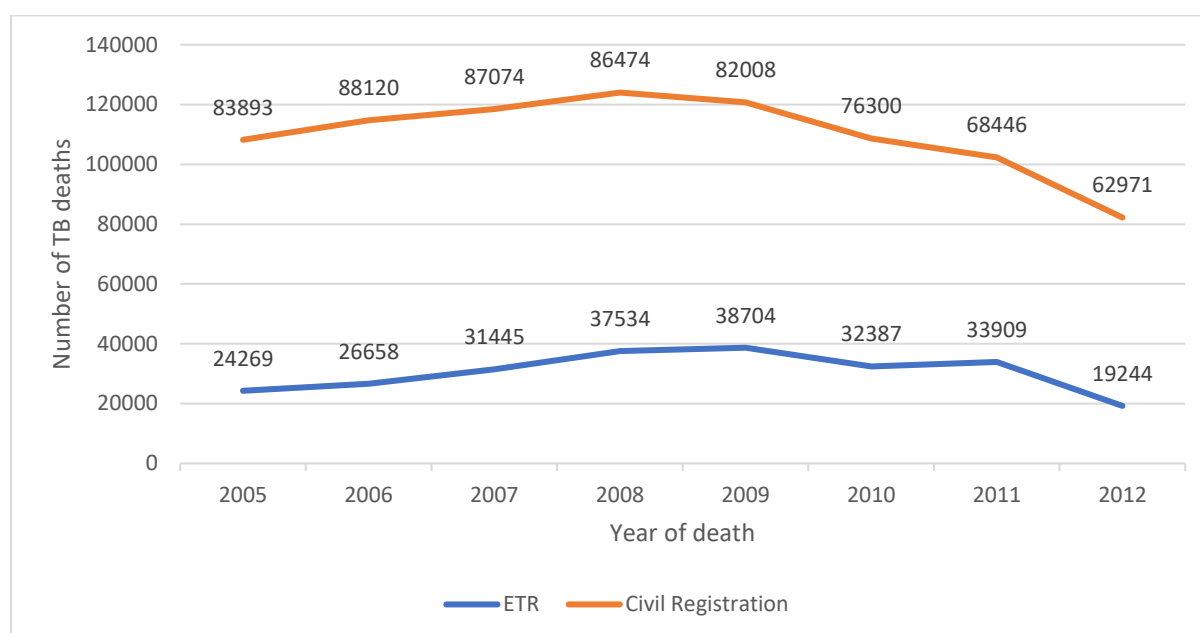
4.2 TB notifications raw data

Raw TB data from the ETR were presented by gender, patient category, type of infection (clinical presentation), treatment and treatment outcome, HIV status, and province. For the period 2005-2012, a total of 3 474 320 TB cases were notified in South Africa, with 2 782 482 being new TB cases and a further 691 838 TB cases made up of those categorised as "relapse", "after default", or "treatment failure". There was a 25.3% increase in the annual number of TB cases notified between 2005 and 2012 (323 175 in 2005 compared to 432 519 in 2012). The highest number of TB notifications was recorded in 2009 (532 018 TB cases). This was the same trend for both male (281 318) and female (250 700) TB cases (see Table 4.4).

4.2.1 TB notification rates for South Africa

There was a steady increase of TB notifications from 689 to 1079 per 100 000 population in 2005 and 2009 respectively, which was then followed by a decrease to 928 per 100 000 population in 2010. The cumulative annual TB notification rate for South Africa for the period under study was 885.2 per 100 000 population at 95% CI [772.0, 945.3]. Overall, trend analysis by simple linear regression revealed that there was no statistically significant trend in the annual TB notification rate of less than one TB case (0.01) per 100 000 population during 2005 to 2012, at 5% significance ($F_{(1,7)} = 3.22$, $p = 0.12$) (See Table 4.5).

4.2.2 TB notifications by gender

Females accounted for 46.5% (1 609 903) of notified TB cases, while males represented 53.5% (1 864 416 cases) of the total 3 474 320 TB notification rates for the period 2005-2012. The difference in the number of cases between males and females was statistically significant (χ^2 (1) = 15711.95, p = <.0001). For the study period, there was a male:female ratio of TB cases of 1.2:1. Throughout the period, male and female TB notification rates followed a similar pattern with males having a consistently higher TB notification rate per 100 000 population than females. The cumulative annual TB notification rate for the study period was higher for males at 974.6 per 100 000 population at 95% CI [858.7,1087.9] in comparison to that of females at 800.2 per 100 000 population at 95% CI [688.1, 906.7]. Trend analysis using simple linear regression showed that there was no statistically significant trend in the annual rate of TB notification of less than 1 TB case (0.01) per 100 000 population for both males and females at 5% significance (F (1,7) = 3.25, p = 0.12) (F (1,7) = 3.17, p = 0.13) respectively (see Table 4.5).

Table 4.4: *Electronic Tuberculosis Register Data by Variable and Year, South Africa 2005-2012 (n = 3 474 320)*

	2005	2006	2007	2008	2009	2010	2011	2012	Total
Total number of TB cases notified	323,175	346,595	403,236	471,043	532,018	464,063	501,671	432,519	3,474,320
Gender									
Male	180,304	189,459	217,854	249,648	281,318	244,202	266,834	234,797	1,864,416
Female	142,871	157,136	185,381	221,395	250,700	219,861	234,837	197,722	1,609,903
Patient Category									
After default (Pulmonary TB)	12,510	12,257	13,976	13,950	13,353	11,350	11,683	9,556	98,635
After failure (Pulmonary TB)	3,435	4,133	5,815	6,616	5,879	4,714	5,055	3,818	39,465
New TB cases	255,351	273,934	323,496	377,598	425,475	368,068	402,246	356,314	2,782,482
Relapse TB cases	48,003	52,337	54,798	49,374	44,384	39,912	41,702	32,212	362,722
All other retreatment cases	2,977	2,907	4,855	15,001	20,629	21,158	23,890	18,273	109,690
Type of infection (Clinical presentation)									
Both	3,619	4,951	4,596	4,661	5,708	4,301	5,076	4,339	37,251
Extra Pulmonary TB	53,984	60,038	64,617	65,198	76,821	65,217	67,506	57,852	511,233
Pulmonary TB	264,672	280,579	333,722	392,658	427,187	375,681	411,994	357,982	2,844,475
Treatment									
Started on treatment	323,175	346,595	403,229	470,993	532,012	464,063	501,671	432,519	3,474,257

	2005	2006	2007	2008	2009	2010	2011	2012	Total
Treatment outcome									
Completed	33,966	37,124	75,576	146,324	183,128	157,588	184,576	40,122	858,404
Cured	158,603	167,892	156,190	131,365	128,904	103,429	124,401	33,215	1,003,999
Defaulted	32,049	30,297	31,002	30,885	31,266	26,313	26,747	8,794	217,353
Died	24,269	26,658	31,445	37,534	38,704	32,387	33,909	19,244	244,150
Failed	3,026	3,148	4,232	5,424	5,596	5,446	6,272	2,523	35,667
Not evaluated	71,262	81,476	104,791	119,510	144,420	138,900	125,766	328,621	1,114,746
HIV status									
Positive	12,628	16,725	28,531	99,089	187,543	220,723	268,190	237,402	1,070,831
Negative	53,824	56,011	72,250	104,672	121,744	11572,4	1439,03	131,547	799,675
Unknown	33	51	1,415	21,938	47,708	35,895	31,892	23,026	161,958
Province									
Eastern Cape	55,045	59,374	65,547	79,429	74,435	70,731	74,801	67,239	546,601
Free State	23,238	25,872	27,498	31,167	31,637	31,430	28,701	25,718	225,261
Gauteng	54,989	55,681	57,412	64,359	66,186	14,757	64,432	56,330	434,146
KwaZulu-Natal	83,590	91,003	123,917	131,194	174,606	167,921	163,799	135,996	1,072,026
Limpopo	16,218	20,568	23,461	28,850	33,670	31,129	30,566	27,298	211,760
Mpumalanga	8	1,546	11,464	32,427	37,597	36,927	34,892	29,415	184,276
North West	32,377	33,581	34,759	38,528	46,492	45,044	40,846	33,750	305,377

	2005	2006	2007	2008	2009	2010	2011	2012	Total
Northern Cape	10,342	10,732	10,978	13,251	13,655	13,095	12,760	9,156	93,969
Western Cape	47,368	48,238	48,200	51,838	53,740	53,029	50,874	47,617	400,904

4.2.3 Type of TB infection

For TB cases notified for the period 2005-2012, 97.6% (339 2993 cases) had the disease category (type of TB infection) recorded as either pulmonary TB or extra pulmonary TB or both. The majority of recorded TB cases 83.8% (2 844 475 cases) were pulmonary TB with 1.1% (37 251 cases) having both pulmonary TB and extra pulmonary TB. Extra pulmonary TB accounted for 15.1% (511 233 cases) of the notified TB cases for the period.

The pulmonary mean TB cumulative annual notification rate for the study period was 723.0 per 100 000 population at 95% CI [633.3, 812.7]. During the period 2005-2012, the pulmonary TB cumulative annual notification rate increased steadily from 564.5 per 100 000 population (264 672 cases) in 2005, to 866.1 per 100 000 population (427 187 cases) in 2009; after which it started to decrease although not to lower than that in 2005. Trend analysis by simple linear regression revealed that the annual increase of less than 1 pulmonary TB case (0.01) per 100 000 population was not statistically significant at 5% significance $(F(1,7) = 3.45, p = 0.11)$ for the study period. For the entire study period, the extra pulmonary TB cumulative annual notification rate was consistently lower than that of the pulmonary TB. Just like pulmonary TB, extra pulmonary TB cumulative annual notification rate increased from 115.1 per 100 000 population (53 984 cases) in 2005 to 155.8 per 100 000 population (76 821 cases) in 2009; and thereafter started to decrease. Trend analysis by simple linear regression showed that the annual increase in notification rate of less than one (0.00) extra pulmonary TB case per 100 000 population was not statistically significant at 5% significance $(F(1,7) = 0.01, p = 0.92)$ for the study period (See Table 4.5).

Table 4.5: *Tuberculosis Notification Rate per 100 000 Population by Gender and Type of Infection in South Africa, 2005-2012*

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
TB notification rate	689	731	843	967	1079	928	998	835
Gender								
Male	782	812	925	1065	1179	1004	1088	932
Female	600	653	763	877	985	857	901	744
Type of TB Infection								
Extra pulmonary TB	115	127	135	134	156	130	133	112
Pulmonary TB	564	592	697	806	866	751	814	691

4.2.4 TB notifications by gender and age group

For the period 2005-2012, the highest cumulative annual notification rate of TB for males was recorded in the 35-44 age group (1 062.2 per 100 000 population; 486 374 cases) while for the females it was among the 25-34 age group (735.5 per 100 000 population; 493 931 cases). The second highest cumulative annual notification rate for TB among males was recorded in the 45-54 age group (883.1 per 100 000 population; 299 601 cases). The second highest cumulative annual notification rate among females was recorded in the 35-44 age group (725.4 per 100 000 population; 332 153 cases). For both males and females, the lowest cumulative annual notification rates were recorded in the 5-14 age group with 96.4 and 101.1 per 100 000 population, respectively. This was the same age group with the lowest cumulative annual notification rate at the national level for the period of study (see Figure 4.2).

Figure 4.2: *Tuberculosis Cumulative Annual Notification Rate per 100 000 Population by Gender and Age Group in South Africa, 2005-2012*
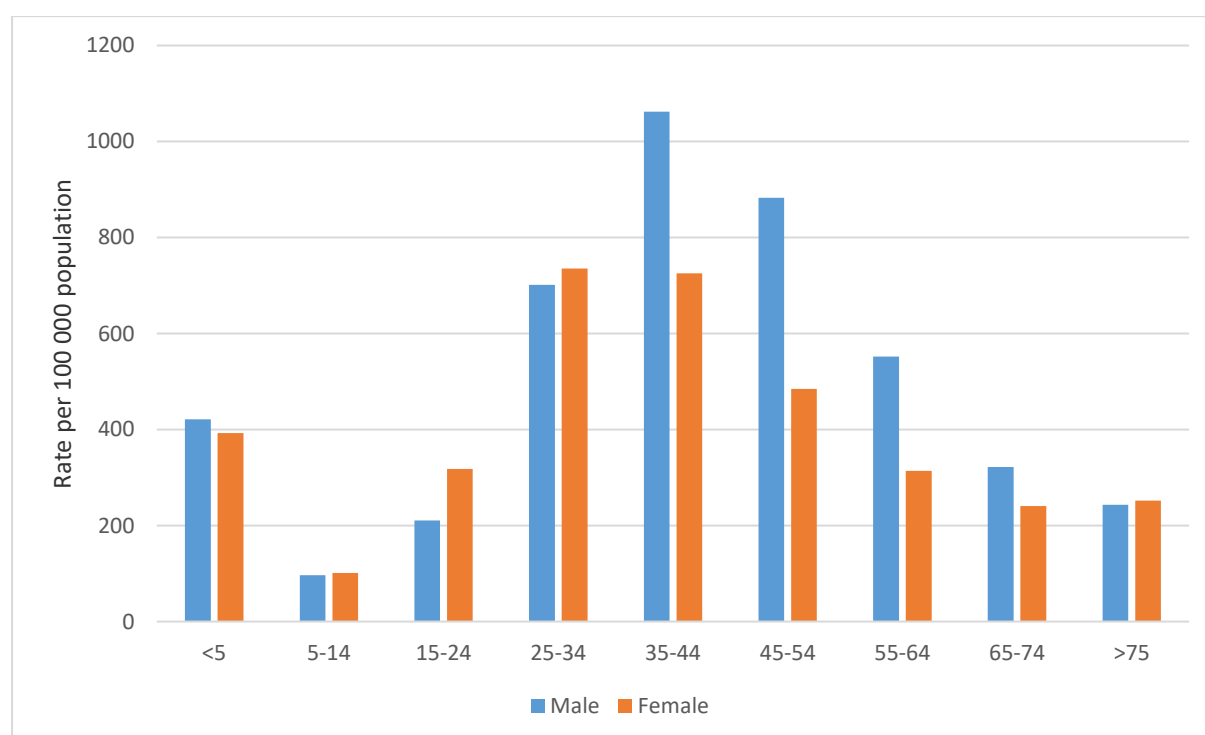
4.2.5 HIV status

Information on whether an HIV test had been carried out was available for 53.8% (1 870 506 cases) for all the notified cases for 2005 to 2012; of these, 30.8% (1 070 831 cases) tested positive for HIV. The proportion of notified TB cases that tested positive for HIV increased steadily from 3.9% (12 628 cases) in 2005 to more than half of the notified TB cases 54.9% (237 402 TB cases) in 2015 (see Figure 4.3).

Figure 4.3: *Proportion of the Human Immunodeficiency Virus Positive Tuberculosis Cases Notified by Year in South Africa, 2005-2012*
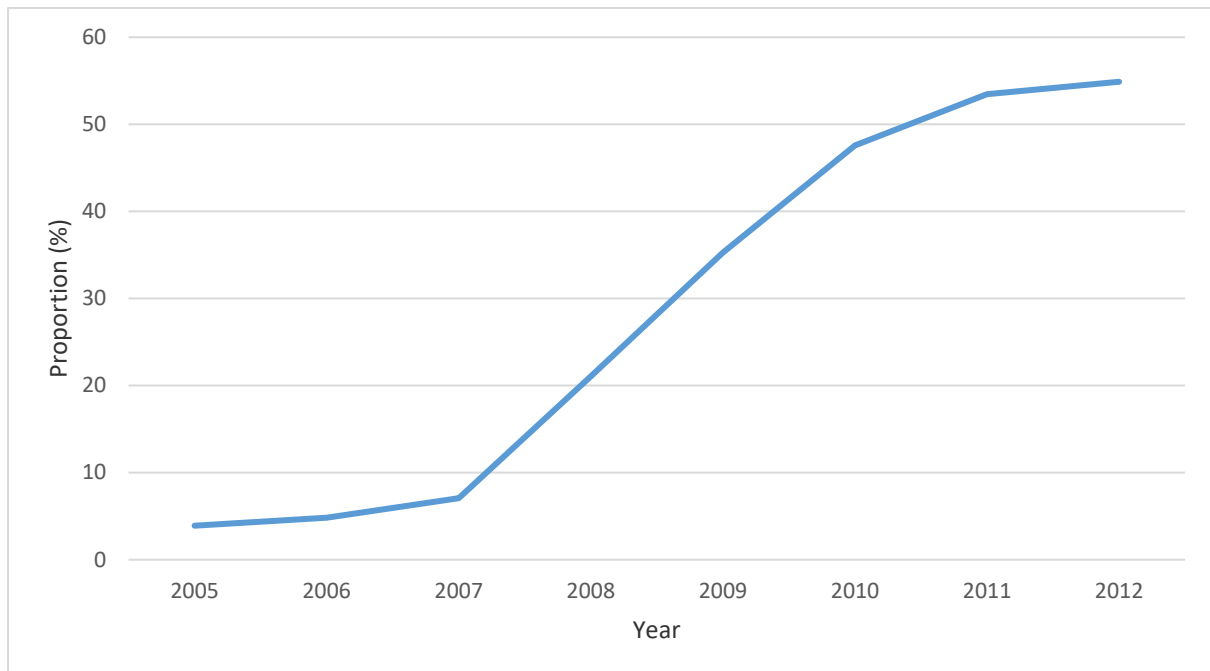
4.2.6 Treatment

For the period 2005-2012, 100% (3 474 275 cases) of the notified TB cases were reported to have started on TB treatment.

4.2.7 Treatment outcome

Out of the total number of TB cases notified for the period 2005-2012, 28.9% (1 003 999 cases) were reported to have been cured at the end of treatment. The proportion of TB cases reported to be cured decreased steadily from 49.1% (158 603 cases) in 2005 to 7.7% (33 215 cases) in 2012. The same trend was observed for the proportion of TB cases that defaulted 6.3% (217 353 cases). In 2005, the proportion of recorded defaulters was 9.9% (32 049 cases) and this decreased to 2.0% (8 794 cases) in 2012 (see Figure 4.4). For the study period, the highest proportion of defaulters was recorded in the 25-34 age group 2.0% (70 009 cases) followed by the 35-44 age group 1.5% (52 062 cases). The lowest proportion of defaulters was recorded in the over 75 age group 0.0% (1 263 cases).

Figure 4.4: *Proportion of Tuberculosis Cases Cured and Defaulted by Year in South Africa, 2005-2012*
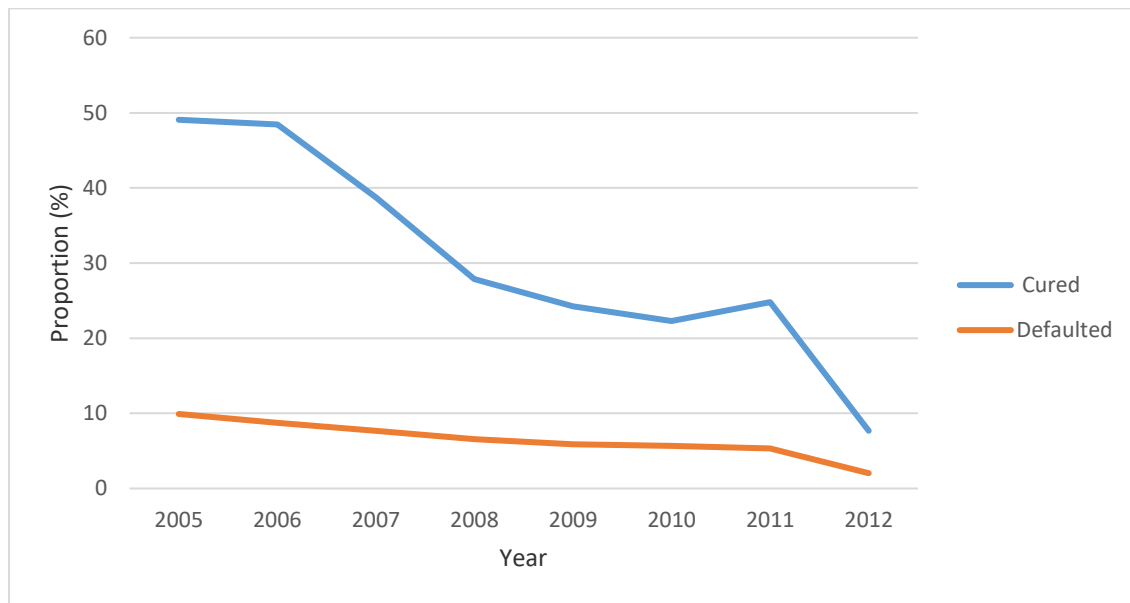
For the period 2005-2012, the proportion of defaulters among males 3.8% (131 926 cases) was higher compared to that of females 2.4% (83 993 cases). For both males and females, the highest proportion of defaulters was recorded among the 25-34 age group 1.2% (42 283 cases) and 0.8% (27 726 cases) respectively. The lowest proportion of defaulters for both males and females was in the over 75 age group 0.0% (640 cases) and 0.0% (623 cases) respectively (see Figure 4.5).

Figure 4.5: *Proportion of Tuberculosis Cases Defaulters by Gender and Age Group in South Africa, 2005-2012*
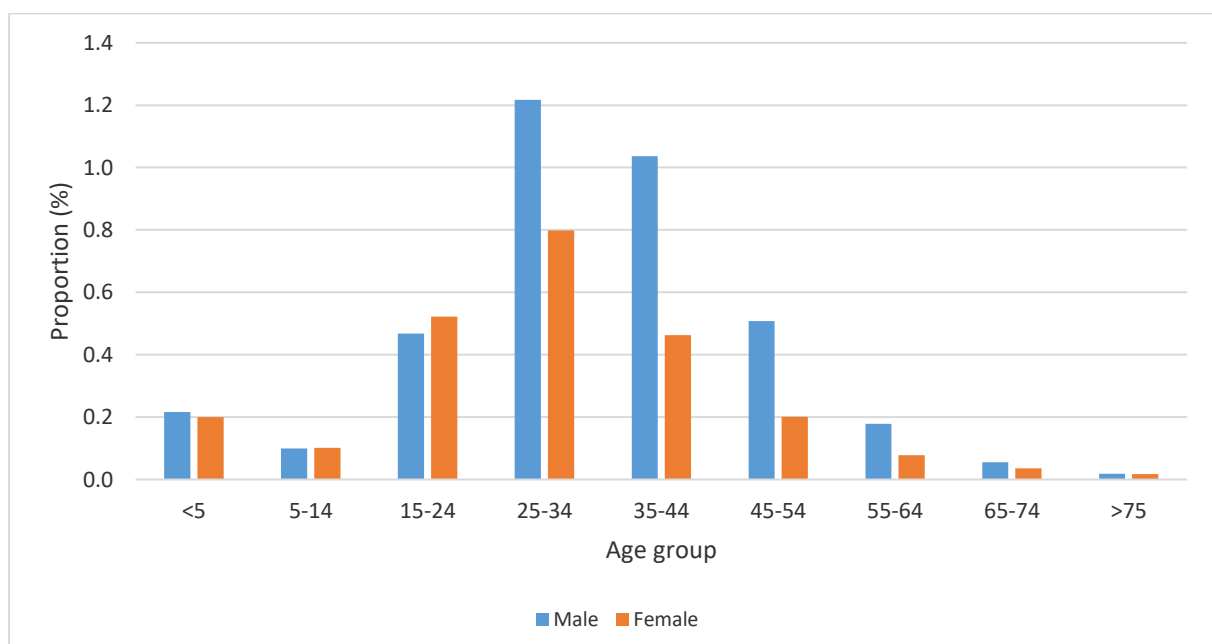
4.2.8 TB relapses

For the period 2005-2012, 17.6% (610 512 cases) of the total number of notified TB cases were relapse/reactivation cases; in fact, 16.2% (98 635 cases) relapsed after defaulting, 6.5% (39 465 cases) after treatment failure and 18% (109 690 cases) after retreatment. The proportion of TB relapse cases notified decreased over the study period, from a high of 20.7% for both 2005 and 2006, to a low of 14.7% in 2012. The annual decrease in the proportion of relapse TB cases notified was statistically significant at 5% significance (F (1,7) = 35.48, p = 0.0008) (see Figure 4.6).

During the period 2005-2012, the proportion of relapse/reactivation TB cases that were notified was more in males than females, 10.7% (370 792 cases) and 6.9% (239 720 cases) respectively.

Figure 4.6: *Proportion of Tuberculosis Relapse Cases Notified in South Africa, 2005-2012*
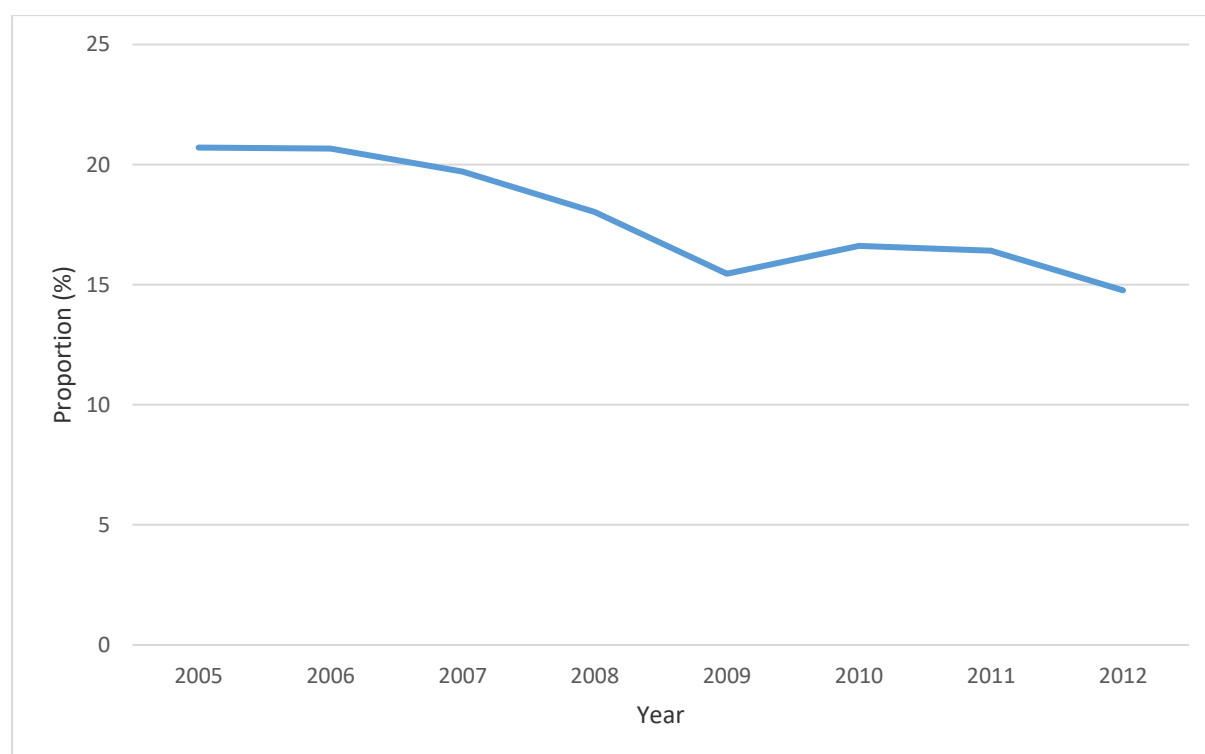
As regards the proportion of relapse/reactivation TB cases notified by age group for the period 2005-2012, age groups 35-44 and 25-34 had the highest notification at 5.4% (186 372 cases) and 5.2% (180 653 cases) respectively. The lowest proportion of relapse/reactivation TB cases was notified by the age groups; the over 75 and under-5 at 0.1% (4 198 cases) and 0.2% (6 074 cases) respectively (see Figure 4.7).

Figure 4.7: *Proportion of Tuberculosis Relapse Cases Notified by Age Group in South Africa, 2005-2012*
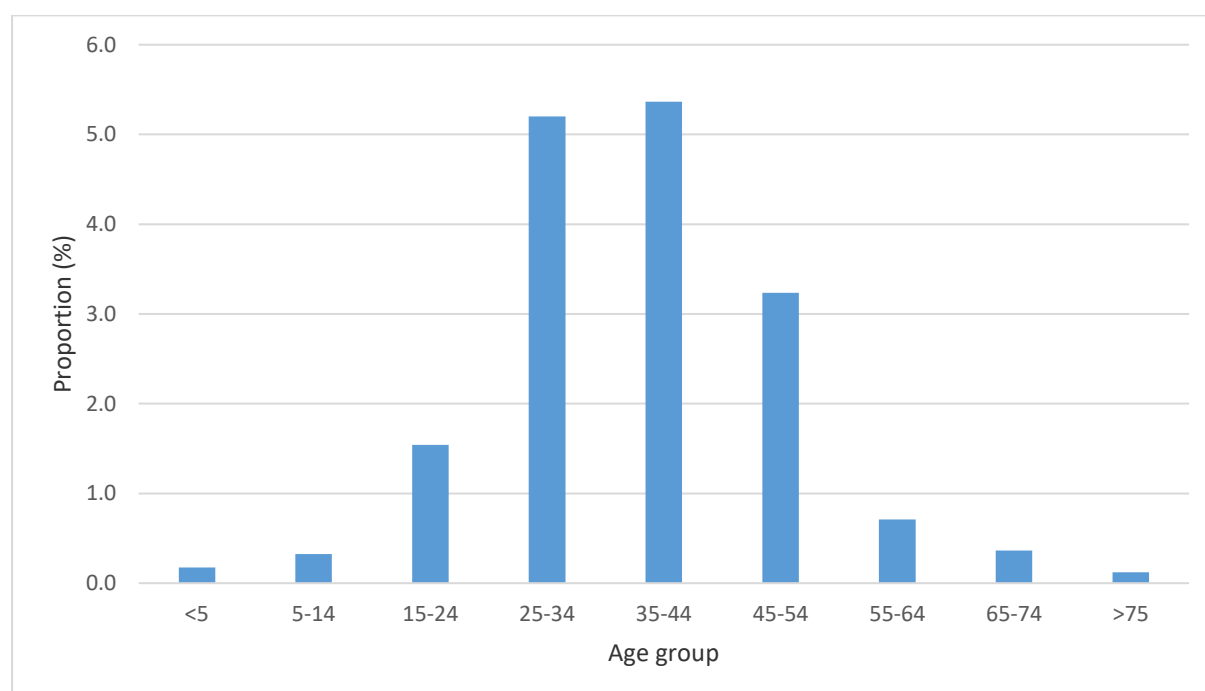
4.2.9 TB deaths notified in the ETR

During 2005 to 2012, 7.0% (244 150 cases) of the notified TB cases were recorded as having died. The cumulative annual death rate for TB for the period 2005-2012 was 62.2 per 100 000 population. The highest proportion of deaths was recorded to be 2.0% of cases in both the 25-34 and 35-44 age groups; while the lowest proportion was recorded at 0.1% in the under-5, 5-14, and over 75 age groups. The proportion of deaths among males 3.8% (133 483 deaths) was slightly higher than that of females 3.2% (110 667 deaths). The denominators used for the proportions were the age or gender specific notification numbers.

4.2.10 TB notification by provinces

Out of the nine provinces, KwaZulu-Natal recorded the highest proportion of TB cases 31% (1 072 026 cases) for the period 2005-2012, followed by Eastern Cape 16% (546 601 cases) which was almost half that recorded in KwaZulu-Natal. Northern Cape province recorded the lowest proportion of TB cases 3% (93 969 cases) for the study period.

For the study period, the mean TB cumulative annual notification rate for provinces was 900.9 per 100 000 population at 95% CI [681.6, 1120.2]. The highest TB cumulative annual notification rate for the period 2005-2012 was recorded in KwaZulu-Natal province 1 309.3 per 100 000 population (1 072 026 cases), followed by North West province 1 113.2 per 100 000 population (305 377 cases). Limpopo province recorded the lowest TB cumulative annual

notification rate 489.0 per 100 000 population (211 760 cases) for the period of study (see Figure 4.8).

Figure 4.8: *Tuberculosis Cumulative Annual Notification Rate per 100 000 Population by Province in South Africa, 2005-2012*
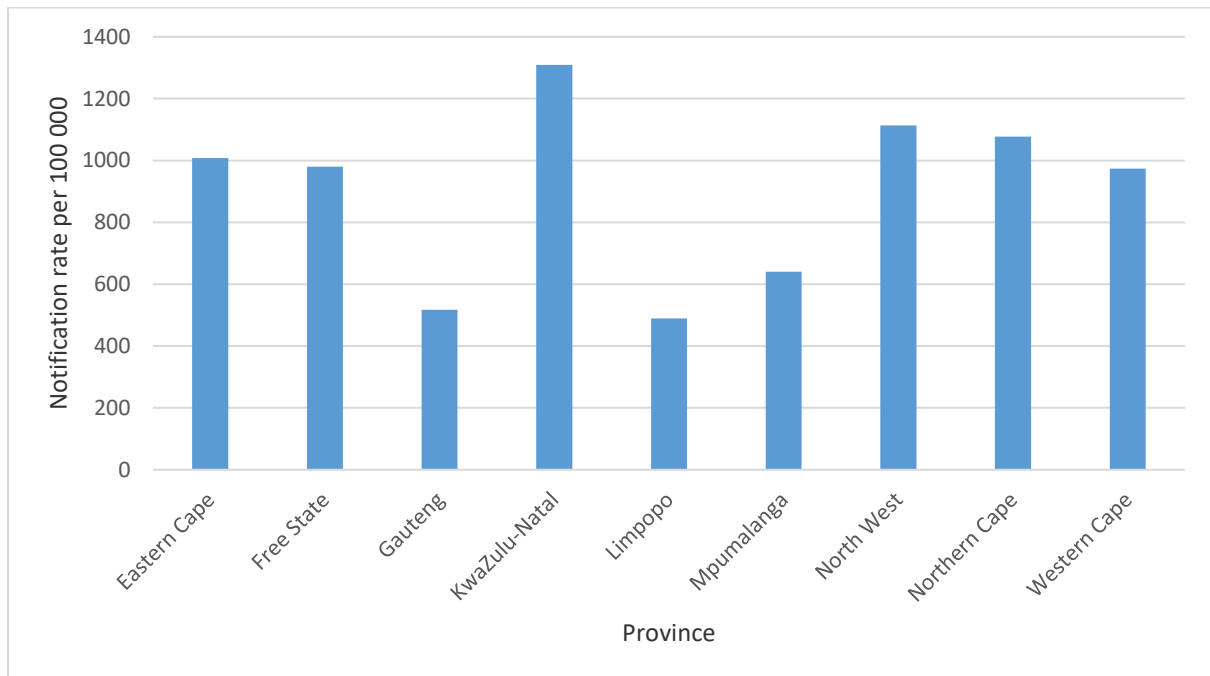
4.2.11 TB notification by district municipalities

South Africa is further divided into 52 district municipalities. The district municipality that recorded the highest proportion of TB cases for the period 2005-2012 was eThekwini metropolitan 11.6% (403 641 cases) followed by Cape Town metropolitan municipality 5.3% (185 315 cases). Central Karoo district municipality 0.1% (4 643 cases) recorded the lowest proportion for the period 2005-2012. However, those district municipalities that had the highest and lowest proportions were not the same ones when the cumulative annual notification rate was considered for the same period. The mean TB cumulative annual notification rate for the district municipalities was 984.0 per 100 000 population at 95% CI [876.9, 1 091.0]. Dr Kenneth Kaunda district municipality 1 927.5 per 100 000 population (104 194 cases) had the highest cumulative annual notification rate, followed by Siyanda 1 651.0 per 100 000 population (30 036 cases). John Taolo Gaetsewe had the lowest cumulative annual notification rate 318.4 per 100 000 population (5 449 cases) (see Table 4.6).

Table 4.6: *Tuberculosis Proportion and Cumulative Annual Notification Rate per 100 000 Population by District Municipality in South Africa, 2005-2012*

District Municipality	TB Cases (n)	Proportion (%)	Rate (per 100 000)
Alfred Nzo	39,505	1.1	620.0
Amajuba	39,204	1.1	981.3
Amathole	45,957	1.3	665.4
Bojanala Platinum	95,037	2.7	835.1
Buffalo City	72,941	2.1	1,213.8
Sarah Baartman	51,798	1.5	1,513.3
Cape Town Metro	185,315	5.3	672.3
Cape Winelands	71,580	2.1	1,234.5
Capricorn	48,773	1.4	496.1
Central Karoo	4,643	0.1	868.6
Chris Hani	58,474	1.7	910.2
Dr. K Kaunda	104,194	3.0	1 927.5
Eden	51,049	1.5	1 215.2
Ehlanzeni	89,021	2.6	679.5
Ekurhuleni Metro	98,958	2.8	418.4
Fezile Dabi	32,137	0.9	815.9
Frances Baard	32,743	0.9	1,147.5
Gert Sibande	57,324	1.6	744.1
Greater Sekhukhune	29,559	0.9	365.8
John Taolo Gaetsewe	5,449	0.2	318.4
Joe Gqabi	23,744	0.7	889.2
Johannesburg Metro	171, 248	4.9	520.6
Lejweleputswa	67,829	2.0	1,348.1
Mangaung Metro	63,314	1.8	994.2
Mopani	46,785	1.3	543.0
Namakwa	7,589	0.2	853.6
Nelson Mandela Metro	115,549	3.3	1,353.4

District Municipality	TB Cases (n)	Proportion (%)	Rate (per 100 000)
Ngaka Modiri Molema	62,769	1.8	961.6
Nkangala	37,931	1.1	391.2
OR Tambo	138,633	4.0	1,307.8
Overberg	22,591	0.7	1,192.9
Pixley Ka Seme	18,152	0.5	1,286.0
Ruth S Mompati	45,172	1.3	1,269.0
Sedibeng	36,538	1.1	549.8
Sisonke	51,149	1.5	1,350.2
Siyanda	30,036	0.9	1,651.0
Thabo Mofutsanyane	47,713	1.4	814.7
Tshwane Metro	114,144	3.3	535.1
Ugu	73,867	2.1	1,407.8
Vhembe	45,414	1.3	449.6
Waterberg	41,228	1.2	752.4
West Coast	32,099	0.9	1,178.3
West Rand	46,885	1.3	684.0
Xhariep	12,473	0.4	1,178.2
Zululand	84,819	2.4	1,303.1
eThekwini Metro	403,641	11.6	1,428.0
iLembe	62,130	1.8	1,314.4
uMgungundlovu	118,407	3.4	1,511.6
uMkhanyakude	64,035	1.8	1,333.2
uMzinyathi	56,334	1.6	1,407.2
uThukela	31,436	0.9	587.7
uThungulu	87,004	2.5	1,176.2

4.2.12 TB notification by health sub district

In addition to districts, South Africa is further divided into 235 health sub districts/local municipalities. Of these, 28 sub districts recorded a proportion of 0.0% for notification of TB cases for the period 2005-2012. The highest proportion of TB cases was notified in eThekwini metropolitan 11.6% (403 640 cases) followed by the City of Johannesburg metropolitan 4.9% (171 248). Nelson Mandela metropolitan had the third highest proportion of notification of TB cases 3.3% (114 781cases) for the study period.

4.3 Epidemiological analysis for TB in Western Cape province

Out of all the nine provinces in South Africa, TB data were made available for only Western Cape for the period 2005-2015. Therefore, the following section is an epidemiological analysis of TB notifications for Western Cape province.

4.3.1 Western Cape province TB notifications

TB raw data for Western Cape province from the ETR for the period 2005-2015 are presented by district municipalities (see Table 4.7).

4.3.2 TB notification in Western Cape province

For the period 2005-2015, the TB notification rate in Western Cape province was highest in 2005 1 019.6 per 100 000 population (47 368 cases); followed by 2006 with 1 016.5 per 100 000 population (48 238 cases). From 2010, the TB notification rate in Western Cape province started decreasing steadily to a low of 712.6 per 100 000 population (44 181 cases). This annual decrease in the TB notification rate of less than 1 TB (0.02) case per 100 000 population was statistically significant at 5% significance ($F_{(1,10)} = 37.08$, $p = 0.0002$) over the study period (see Figure 4.9).

Table 4.7 *Electronic Tuberculosis Register Data by District Municipality, Sub District, and Year; Western Cape Province 2005-2015 (n = 505 398)*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Total number of TB cases notified	43,530	44,344	44,138	47,517	49,187	48,180	46,627	43,754	47,992	45,958	44,171	505,398
District Municipality												
Cape Town Metro	22,030	22,383	22,515	24,233	24,129	24,363	23,549	22,113	26,676	25,882	24,995	262,868
Cape Winelands	8,956	8,848	8,288	9,016	9,599	9,222	9,158	8,493	8,436	8,155	7,549	95,720
Central Karoo	394	542	595	558	552	668	684	650	650	679	615	6,587
Eden	5,776	6,183	6,500	7,066	7,271	6,387	6,205	5,661	5,615	5,277	4,948	66,889
Overberg	2,764	2,610	2,519	2,858	3,060	3,049	2,970	2,761	2,494	2,193	2,242	29,520
West Coast	3,610	3,778	3,721	3,786	4,576	4,491	4,061	4,076	4,121	3,772	3,822	43,814
Subdistrict/Local Municipality (LM)												
Laingsburg LM	92	106	74	86	110	105	92	78	64	73	71	951
Prince albert LM	131	123	166	155	150	160	136	129	124	130	113	1,517
Cape Agulhas LM	213	267	272	248	273	282	270	258	210	207	196	2,696
Kannaland LM	209	282	297	296	359	319	318	263	314	218	220	3,095
Swellendam LM	313	349	368	336	402	342	374	351	296	286	245	3,662
Beaufort West LM	170	313	355	317	292	352	388	370	462	476	431	3,926
Hessequa LM	319	365	389	389	511	433	368	422	400	349	380	4,325
Bitou LM	253	488	653	684	577	567	473	485	379	382	409	5,350
Bergrivier LM	473	470	456	486	622	635	554	507	581	492	499	5,775

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Cederberg LM	561	601	628	604	993	760	686	625	667	642	706	7,473
Knysna LM	938	706	819	871	735	645	577	528	514	571	581	7,485
Overstrand LM	763	684	637	760	770	860	928	833	697	601	687	8,220
Swartland LM	849	878	820	892	943	974	847	805	742	862	882	9,494
Saldanha Bay LM	837	838	835	885	1,006	1,061	879	1,025	962	774	797	9,899
Matzikama LM	890	991	982	919	1,012	1,061	1,095	1,114	1,169	1,002	938	11,173
Mossel Bay LM	996	1,236	1,077	1,179	1,254	1,011	1,127	932	922	799	796	11,329
Oudtshoorn LM	1,094	994	1,100	1,356	1,593	1,302	1,154	973	1,122	1,037	858	12,583
Stellenbosch LM	1,154	1,305	1,152	1,324	1,381	1,412	1,320	1,203	1,331	1,253	1,160	13,995
Langeberg LM	1,099	1,126	1,065	1,369	1,583	1,371	1,542	1,527	1,289	1,143	1,009	14,123
Witzenberg LM	1,445	1,396	1,265	1,366	1,591	1,405	1,507	1,258	1,343	1,209	1,122	14,907
Theewaterskloof LM	1,475	1,310	1,242	1,514	1,615	1,565	1,398	1,319	1,291	1,099	1,114	14,942
George LM	1,857	1,985	2,034	2,168	2,110	1,984	2,076	1,927	1,964	1,921	1,704	21,730
Breede Valley LM	2,597	2,319	2,098	2,139	2,205	2,364	2,383	2,197	2,057	2,269	2,114	24,742
Drakenstein LM	2,661	2,702	2,708	2,818	2,839	2,670	2,406	2,308	2,416	2,282	2,145	27,955
Cape Town MM	25,623	26,008	26,216	28,205	28,259	28,765	27,473	25,616	26,681	25,887	25,004	293,737

Figure 4.9: *Tuberculosis Notification Rate per 100 000 Population by Year in Western Cape Province, 2005-2015*
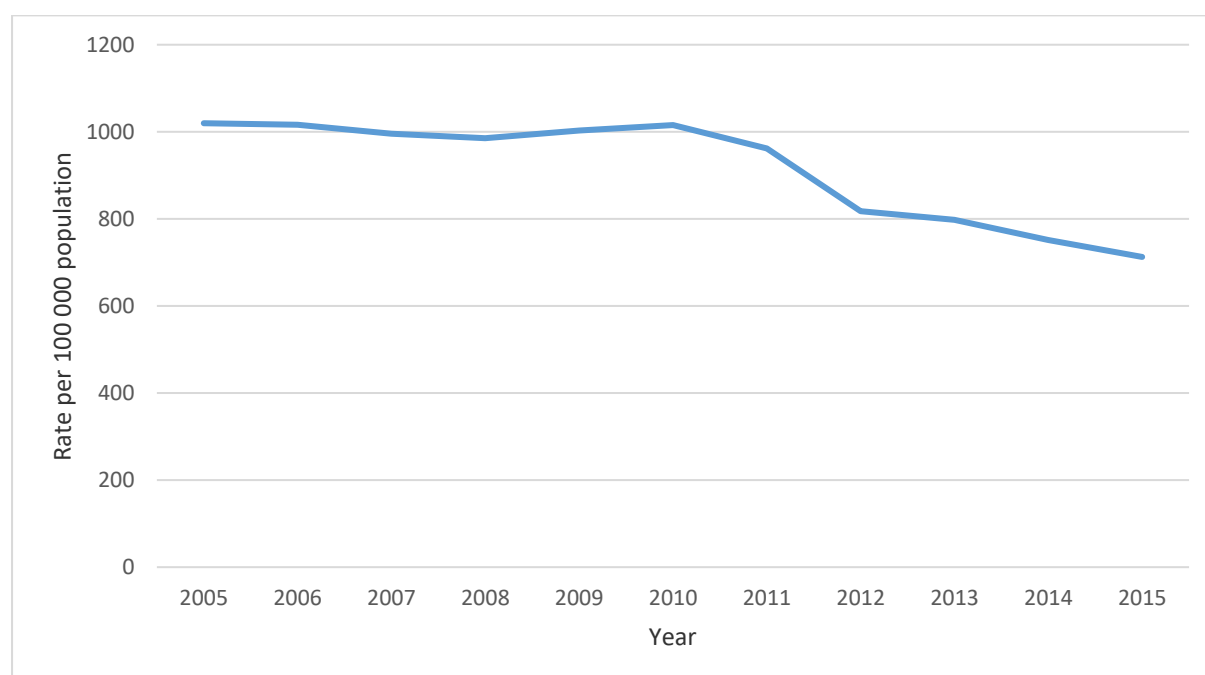
4.3.3 TB notification by districts in Western Cape province

Out of the six districts of Western Cape province, only the Central Karoo district municipality had a steady increase of TB notification rate for the period 2005-2015. For the year 2005, the highest TB notification rate was recorded in the Cape Winelands district municipality 1 331.3 per 100 000 population (8 956 cases); followed by Overberg 1 264.1 per 100 000 population (2 764 cases). For 2015, the highest TB notification rate was in West Coast district municipality and the lowest in Cape Town metropolitan municipality 930.4 per 100 000 population (3 822 cases) and 625.2 per 100 000 population (24 995 cases) respectively (see Figure 4.10).

4.3.4 TB notification by health sub districts/local municipalities in Western Cape province

Western Cape province has 25 health sub districts/local municipalities. During the period 2005-2015, Western Cape province notified 534 960 TB cases. The highest proportion of notified TB cases in Western Cape province for the period of study was the City of Cape Town metropolitan 54.9% (293 737 cases) which notified more than half of the total number of TB cases. The second and third highest proportion of TB notifications were in the Drakenstein and Breede Valley sub districts 5.2% (27 955 cases) and 4.6% (24 742 cases) respectively. The lowest proportion of TB notifications was recorded in Laingsburg sub district 0.7% (951 cases), closely followed by Prince Albert sub district 0.8% (1 517 cases) for the period 2005-2015 (see Table 4.8).

Table 4.8: *Proportion of Tuberculosis Notification by Sub District/Local Municipality in Western Cape Province, 2005-2015*

Sub district/Local Municipality	TB Cases (n)	Proportion (%)
Laingsburg LM	951	0.2
Prince Albert LM	1,517	0.3
Cape Agulhas LM	2,696	0.5
Kannaland LM	3,095	0.6
Swellendam LM	3,662	0.7
Beaufort West LM	3,926	0.7
Hessequa LM	4,325	0.8
Bitou LM	5,350	1.0
Bergrivier LM	5,775	1.1
Cederberg LM	7,473	1.4
Knysna LM	7,485	1.4
Overstrand LM	8,220	1.5
Swartland LM	9,494	1.8
Saldanha Bay LM	9,899	1.9
Matzikama LM	11,173	2.1
Mossel Bay LM	11,329	2.1
Oudtshoorn LM	12,583	2.4
Stellenbosch LM	13,995	2.6
Langeberg LM	14,123	2.6
Witzenberg LM	14,907	2.8
Theewaterskloof LM	14,942	2.8
George LM	21,730	4.1
Breede Valley LM	24,742	4.6
Drakenstein LM	27,955	5.2
Cape Town MM	293,737	54.9

Figure 4.10: *Tuberculosis Notification Rate per 100 000 Population by District and Year in Western Cape Province, 2005-2015*
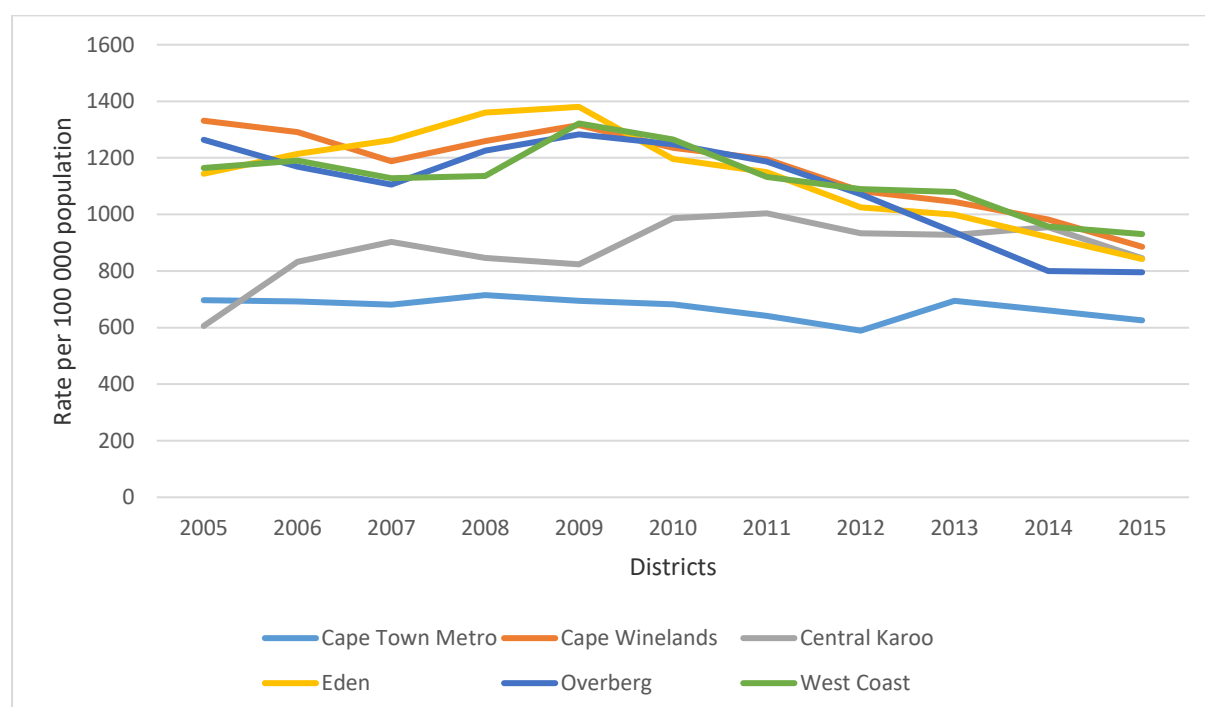
4.4 TB deaths

The mortality data had 391 duplicate TB deaths that were identified and removed. Absolute numbers of TB deaths by demographics, level of education, occupation group, type of occupation industry, smoking status of deceased, method of ascertainment of death, place or institution of death, and province are shown in Table 4.13. For the period 2005-2015 there were 776 176 TB deaths in South Africa. There was a 61.0% decrease in the annual number of TB deaths between 2005 and 2015 (83 893 TB deaths in 2005 compared to 32 713 TB deaths in 2015). The highest proportion of TB deaths was 11.8% (88 120) and was recorded in 2006; while the lowest was 4.2% (32 713 TB deaths) in 2015 (see Table 4.13; Appendix F).

4.4.1 TB death rates for South Africa 2005-2015

There was a steady decrease of the TB death rates from 2006 to 2015. The mean annual cumulative TB death rate for the study period was 142.2 at 95% CI [114.2, 170.2]. The rate of TB deaths was highest in 2006 (185.9 per 100 000 population) which was three times the lowest rate in 2015 (59.5 per 100 000 population). Overall, there was a statistically significant decrease in TB deaths of less than 1 TB death (0.01) per 100 000 population annually at 5% significance $(F(1,10) = 93.58, p = 0.001)$ for the period 2005-2015 (see Table 4.9).

4.4.2 TB death rates by gender

Males accounted for 55.5% while females 44.3% of the total 776 176 TB deaths for the period 2005-2015. The mean cumulative annual TB death rates for males and females were 161.5 per 100 000 population at 95% CI [132.9, 190.0] and 123.2 per 100 000 population at 95% CI [95.6, 150.8] respectively. Throughout the period, male and female TB death rates followed a similar pattern with males having a consistently higher TB death rate per 100 000 population than females. The cumulative annual TB death rate for both males and females decreased over the study period. The cumulative annual TB death rate for the study period was higher for males (225.3 per 100 000 population) in comparison to that of females (171.1 per 100 000 population) (see Table 4.9).

Table 4.9: *Tuberculosis Death Rates per 100 000 Population by Year and Gender in South Africa, 2005-2015*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
TB death rate	179	186	182	178	166	153	135	122	107	98	60
Gender											
Male	196	203	199	200	189	174	156	142	126	117	74
Female	162	168	165	156	145	132	114	101	88	79	45

4.4.3 TB deaths by gender and age group

For the period 2005-2015, the highest cumulative annual TB death rate for both males and females was recorded in the 35-44 age group, 194.7 per 100 000 population (129 724) and 134.3 per 100 000 population (89 480) respectively. The second highest cumulative annual TB death rate among males was recorded in the 45-54 age group (188.6 per 100 000 population; 92 432 TB deaths), whereas, the second highest cumulative annual TB death rate among females was recorded in the 25-34 age group (117.6 per 100 000 population; 111 651 TB deaths). For both males and females, the lowest cumulative annual TB death rate was recorded in the 5-14 age group with 4.5 and 4.2 per 100 000 population respectively for the period of study (see Figure 4.11).

4.4.4 TB deaths by population group or race

As mentioned earlier, the population of South Africa is classified into four population groups or races; black African, White, Coloured, and Indian or Asian. For the period 2005-2015, 18.8% (146 140 TB deaths) of TB deaths had an unspecified population group. The highest proportion of TB deaths was recorded in the black African population group 76.3% (592 945

TB deaths), which was more than three quarters the total number of TB deaths for the period of study. The Coloured population group recorded the second highest deaths 4.1% (31 493); followed by the White population group which recorded 0.4% (3 284 TB deaths) of the total number of TB deaths. The Indian or Asian population group 0.3% (2 314 TB deaths) had the lowest proportion of TB deaths for 2005 to 2015. The cumulative annual TB death rate was also highest in the black African population group 136.3 per 100 000 population; followed by the Coloured population group 63.8 per 100 000 population for the period of study.

Figure 4.11: *Tuberculosis Cumulative Annual Death Rate per 100 000 Population by Gender and Age Group in South Africa, 2005-2015*
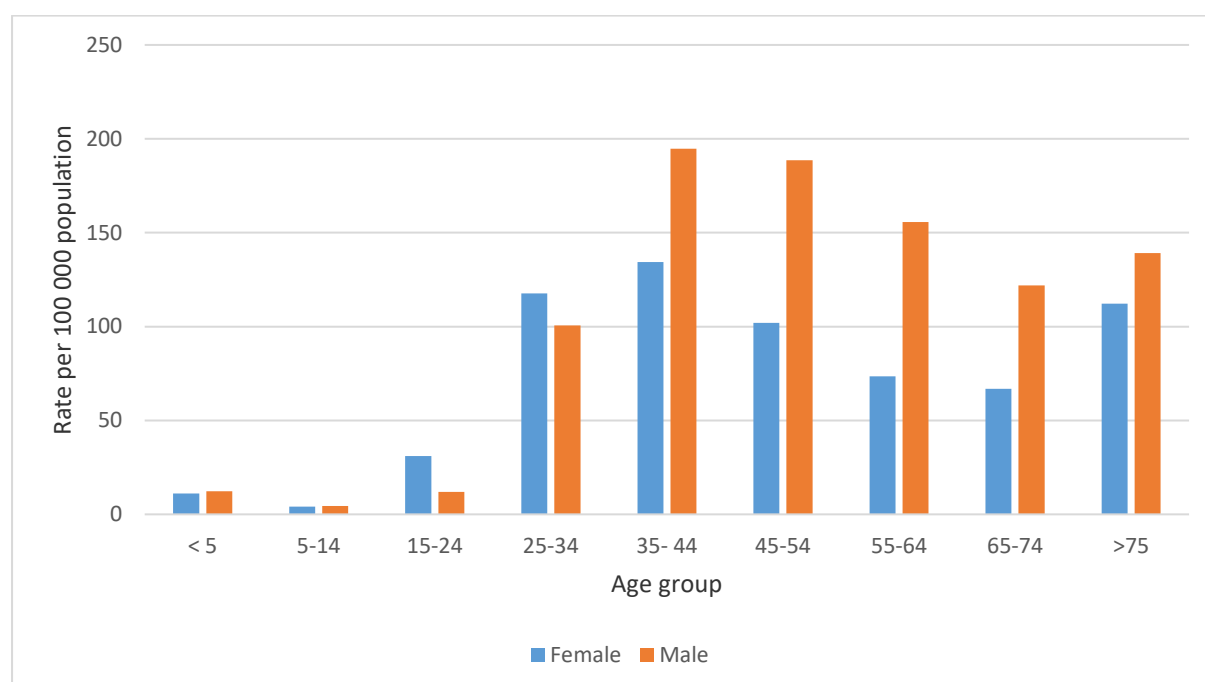
4.4.5 TB deaths by level of education
Out of the total number of TB deaths for the 2005 to 2015 period, 47.4% (368 224) had an unspecified level of education; 2.4% (18 321) were unknown; and a further 1.5% (12 001 TB deaths) recorded as not applicable. Among those that had a level of education recorded for the period of study, the proportions of TB deaths are presented in Figure 4.12.

4.4.6 TB deaths by occupation group
For the period 2005-2015, a proportion of 13.4% of TB deaths (104 125) recorded the occupation group as not applicable. For those that had an occupation group recorded, the highest proportion 73.6% (572 186 TB deaths) was in the Armed forces, occupations unspecified and not elsewhere classified, and not economically active persons. Those that were in the elementary professions occupation group followed with the second highest proportion

5.9% (45 492 TB deaths). The lowest proportion of TB deaths 0.2% (1 735 TB deaths) comprised legislators, senior officials, and managers for the study period (see Table 4.10).

Figure 4.12: *Proportion of Tuberculosis Deaths by Level of Education in South Africa, 2005-2015*
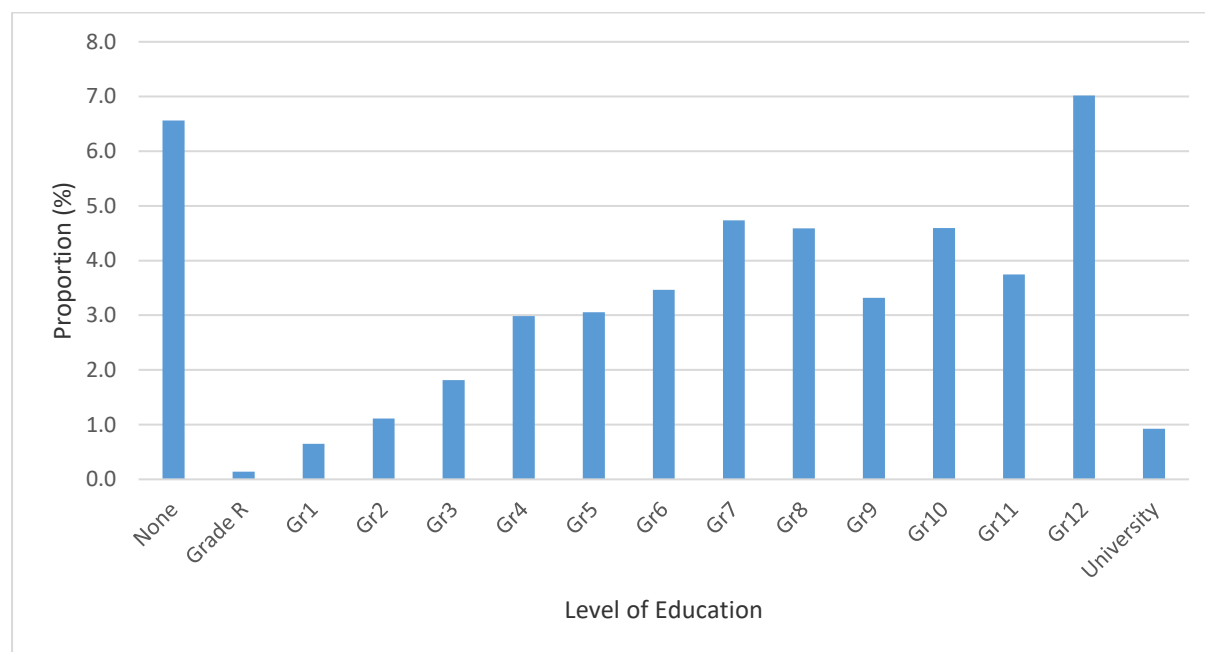
Table 4.10: *Proportion of Tuberculosis Deaths by Occupation Group, South Africa 2005-2015*

Occupation group	TB deaths	Proportion (%)
Armed forces, occupations unspecified and not elsewhere classified, and not economically active persons	572,186	73.6
Legislators, senior officials, and managers	1,735	0.2
Professionals	5,033	0.6
Technicians and associate professionals	2,128	0.3
Clerks	3,313	0.4
Service workers, shop, and market sales workers	11,858	1.5
Skilled agricultural and fishery workers	4,705	0.6
Craft and related trade workers	13,174	1.7
Plant and machine operators and assemblers	13,427	1.7
Elementary occupations	45,492	5.9
Not applicable	104,125	13.4

4.4.7 TB deaths by industry of occupation

Industry in South Africa comprises 8 categories, but the TB mortality data had 10 groupings. A proportion of 3.4% of the reported TB deaths (23 466) had the occupation industry category recorded as not applicable for the period 2005-2015. For the period of study, the highest proportion of TB deaths 62.0% (482 049) was recorded in the private households, exterritorial organisations, representatives of foreign governments, and other activities not adequately defined industry category. The second highest proportion of TB deaths 14.5% (112 326) was in the community, social, and personal services industry category. The lowest proportion of TB deaths 0.2% (1 429) was in the electricity, gas, and water supply industry category for the study period (see Table 4.11).

Table 4.11: *Proportion of Tuberculosis Deaths by Industry Category, South Africa 2005-2015*

Industry	TB deaths	Proportion (%)
Private households, exterritorial organisations, representatives of foreign governments and other activities not adequately defined	482,049	62.0
Agriculture, hunting, forestry and fishing	14,674	1.9
Mining and quarrying	9,993	1.3
Manufacturing	5,123	0.7
Electricity, gas, and water supply	1,429	0.2
Construction	7,855	1.0
Wholesale and retail trade, repair of motor vehicles, motor cycles and personal and households goods, hotels and restaurants	16,029	2.1
Transport, storage, and communication	28,132	3.6
Financial intermediation, insurance, real estate, and business services	76,100	9.8
Community, social, and personal services	112,326	14.5
Not applicable	23,466	3.0

4.4.8 TB deaths by smoking status of the deceased

Almost half of the TB deaths 45.4% (352 604) for the period 2005-2015 had their smoking status recorded as unspecified. However, for those that had smoking status recorded, the highest proportion was among those recorded as non smokers 30.9% (239 988 TB deaths), almost twice compared to the proportion of those who were smokers 15.8% (122 477 TB deaths).

4.4.9 TB deaths by method of ascertainment of the cause of death

During 2005 to 2015, 11.6% (90 473 TB deaths) and 0.3% (2 233 TB deaths) had an unspecified and an unknown method used for ascertainment of the cause of death, respectively. Ascertainment of the cause of death by post-mortem examination was used mostly 31.5% (244 843) to ascertain TB deaths followed by opinion of attending medical practitioner 25.0% (194 612). These two methods combined accounted for more than half of the TB deaths that had ascertainment of the cause of death recorded. In addition to those that had a method of ascertainment of death specified, interview of family member accounted for 3.2% (24 551) of all TB deaths for the period 2005-2015.

4.4.10 TB deaths by place or institution of death

For the period under study, those TB deaths that had a place or institution of death unspecified were 10.4% (81 083) and 0.1% (1 085) were unknown; whereas those with the place or institution of death recorded as other were 1.2% (9 431 TB deaths). For those TB deaths that had a place or institution of death specified, majority of them died at the hospital 64.3% (499 998), followed by 19.9% (154 714 TB deaths) dying at home in the period 2005-2015. The least number of deaths for the study period occurred at a nursing home 1.0% (7 468 TB deaths).

4.4.11 TB deaths by province of death

KwaZulu-Natal province recorded the highest proportion of TB deaths 26.3% (203 888) for the period 2005-2015, followed by Eastern Cape province 14.8% (114 947 TB deaths). Northern Cape province recorded the lowest proportion of TB deaths 2.4% (18 465) for the study period.

For the study period, the mean cumulative annual TB death rate for the provinces was 132.3 per 100 000 population at 95% CI [101.9, 162.4]. The highest cumulative annual TB death rate for the period 2005-2015 was recorded in KwaZulu-Natal province 178.9 per 100 000 population, closely followed by Free State province 172.1 per 100 000 population (53 940 TB deaths). Western Cape province recorded the lowest cumulative annual TB death rate 76.5 per 100 000 population (45 513 TB deaths) for the period of study (see Figure 4.13).

Figure 4.13: *Cumulative Annual Tuberculosis Death Rate per 100 000 Population by Province in South Africa, 2005-2015*
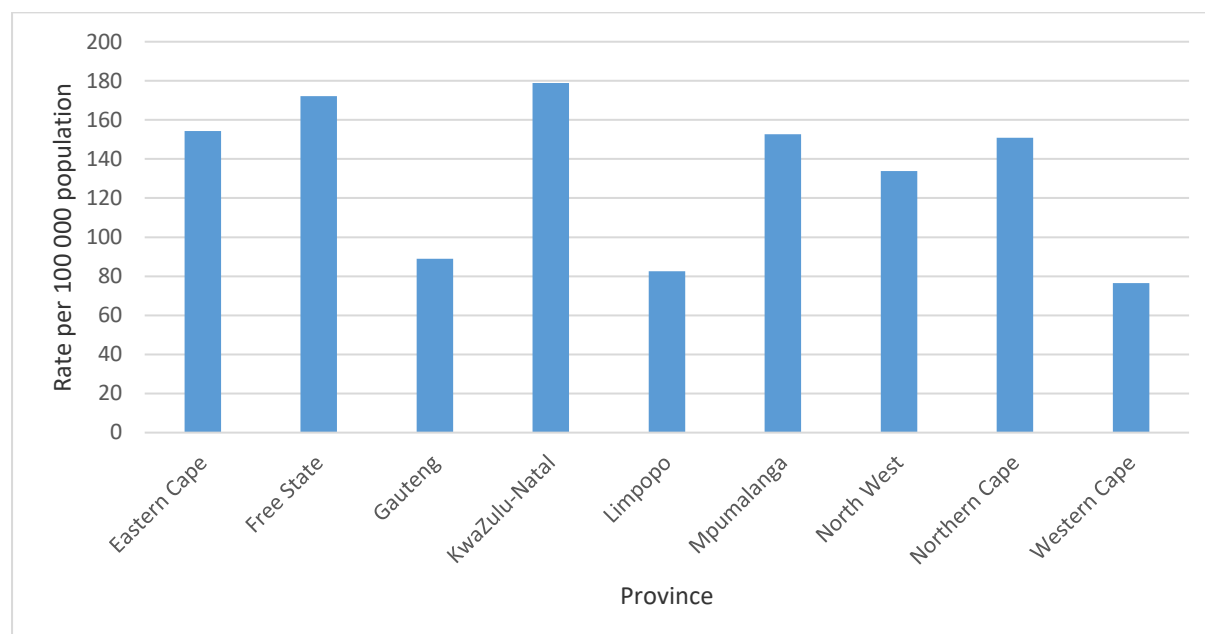
4.4.12 TB deaths by district municipality of death

A proportion of 1.0% (7 763), 0.3% (2 037) and 0.1% (592) of TB deaths had their district of death as unspecified, outside of South Africa, and unknown, respectively for the period of study. During the same period of study, the highest proportion of TB deaths were in eThekwini metropolitan municipality 7.5% (57 908) followed by Ekurhuleni metropolitan municipality 4.5% (36 584). Namakwa and Central Karoo district municipalities both had the lowest proportion of TB deaths 0.1% (862 and 1 014) respectively for the period 2005-2015. The mean annual cumulative TB death rate for the district municipalities for the study period was 155.5 per 100 000 population at 95% CI [139.6, 171.4]. For the cumulative annual TB death rate, Ugu district municipality had the highest at 312.0 per 100 000 population (22 722 TB deaths); followed by Amathole district municipality 233.1 per 100 000 population (21 791 TB deaths). Vhembe and Overberg district municipalities had the lowest cumulative annual TB death rates 66.1 per 100 000 population (9 348 TB deaths) and 66.3 per 100 000 population (1 800 TB deaths) respectively for the period of study (see Table 4.12).

Table 4.12: *Tuberculosis Proportion and Cumulative Annual Tuberculosis Death Rate per 100 000 Population by District Municipality in South Africa, 2005-2015*

District municipality	TB deaths (n)	Proportion (%)	Rate (per 100 000)
Alfred Nzo	7,664	1.0	87.4
Amajuba	10,234	1.3	183.3
Amathole	21,791	2.8	233.1
Bojanala Platinum	15,438	2.0	95.2
Buffalo City	19,148	2.5	228.9
Sarah Baartman	7,700	1.0	160.8
Cape Town Metro	32,487	4.2	82.6
Cape Winelands	8,357	1.1	100.8
Capricorn	15,076	1.9	110.5
Central Karoo	1,014	0.1	135.5
Chris Hani	15,138	1.9	173.4
Dr. K Kaunda	16,715	2.2	218.2
Eden	6,668	0.9	112.5
Ehlanzeni	32,066	4.1	175.2
Ekurhuleni Metro	36,584	4.7	108.5
Fezile Dabi	8,293	1.1	152.0
Frances Baard	7,318	0.9	183.8
Gert Sibande	18,558	2.4	169.5
Greater Sekhukhune	10,176	1.3	90.8
Harry Gwala	11,995	1.5	226.4
John Taolo Gaetsewe	2,379	0.9	98.3
Joe Gqabi	6,852	0.3	188.1
Johannesburg Metro	34,428	4.4	72.1
Lejweleputswa	1,4370	1.8	205.4
Mangaung Metro	14,553	1.9	164.3
Mopani	10,458	1.3	86.9
Namakwa	862	0.1	70.6

District municipality	TB deaths (n)	Proportion (%)	Rate (per 100 000)
Nelson Mandela Metro	22,115	2.8	184.9
Ngaka Modiri Molema	14,653	1.9	159.0
Nkangala	14,773	1.9	106.3
OR Tambo	20,244	2.6	138.0
Overberg	1,800	0.2	66.3
Pixley Ka Seme	4,302	0.6	217.5
Ruth S Mompati	8,909	1.1	182.6
Sedibeng	12,306	1.6	132.4
Thabo Mofutsanyane	15,082	1.9	185.9
Tshwane Metro	25,825	3.3	83.9
Ugu	22,722	2.9	312.0
Vhembe	9,348	1.2	66.1
Waterberg	6,684	0.9	86.5
West Coast	4,456	0.6	113.9
West Rand	12,551	1.6	129.9
Xhariep	3,239	0.4	222.6
Z F Mgcawu	4,220	0.5	163.9
Zululand	17,875	2.3	194.7
eThekwini Metro	57,908	7.5	145.4
iLembe	14,057	1.8	214.0
uMgungundlovu	24,223	3.1	221.4
uMkhanyakude	12,457	1.6	186.5
uMzinyathi	12,810	1.6	231.4
uThukela	15,511	2.0	210.3
uThungulu	22,392	2.9	216.5

4.4.13 TB deaths by sub district or local municipality of death

Twenty six sub districts/local municipalities had a proportion of 0.0% of the TB deaths for the period 2005-2015. The highest proportion of TB deaths was in eThekwini metropolitan municipality 7.5% (57 907 TB deaths) followed by Ekurhuleni metropolitan municipality 4.7% (36 446 TB deaths) for the study period.

4.5 Summary

This chapter has presented results of the evaluation of the TB surveillance system and the epidemiological and inferential analysis of the ETR and mortality TB data in South Africa. The date of birth variable for the ETR presented very low completeness whereas for the TB mortality data, the smoking status, and the level of education of the deceased had low completeness. The findings for timeliness were that 14% of the TB cases in Western Cape province were started on TB treatment within 48 hours, which is the recommended time period. In addition, the study revealed that there was a delay in initiating treatment to the majority of TB cases. Furthermore, the study revealed that the total number of TB deaths recorded in the ETR were not equal to those in the civil registration system; in fact, they were much less where the ETR was only able to identify approximately 39% of TB deaths.

For the period 2005-2012 there was a slight increase in the cumulative annual TB notification rate for South Africa—this is in contrast to the decrease in Western Cape province for the period 2005-2015. The highest annual notification rate of TB for males was observed in the 35-44 age group; and for females among the 25-34 age group. KwaZulu-Natal province and eThekwini metropolitan municipality recorded the highest proportion of TB cases. Furthermore, KwaZulu-Natal province and Dr Kenneth Kaunda district municipality had the highest TB cumulative annual notification rates.

There was a statistically significant decrease in the cumulative annual TB death rate for the period 2005-2015 for South Africa. Tuberculosis affected more males than females; with more deaths in the 35-44 age group for both males and females. KwaZulu-Natal province and eThekwini metropolitan municipality recorded the highest proportion of TB deaths. This chapter has provided information on the trends of TB notifications and deaths for the period 2005-2015. The analysis confirmed the hypothesis that there is geographical variation in TB notification and death rates across South Africa. This information is valuable for health workers involved in TB control activities in the country. The next chapter presents the results of the

geospatial analysis of TB notification and death rates in South Africa for the periods 2005 and 2010.

Chapter 5 - Results: Geospatial Analysis

5.0 Introduction

The previous chapter presented results of the evaluation of the surveillance system and the results of epidemiological and inferential analysis of TB notification and death rates. This chapter will begin by presenting a map of South Africa with the 52 district municipality names to show the reader where they are located (see Figure 5.1). This will be followed by results of the spatial analysis of completeness of date of birth for the TB notifications (2005 to 2012) and for the smoking variable for the deceased (2005 to 2015), then the unadjusted TB notification rates (overall, male and female) for the district municipalities in South Africa for 2005 and 2010. Next to be presented will be the age sex standardised TB notification and death rates for the periods 2005 and 2010, followed by presenting the results of the Global Moran's I and raw box maps for the same study period. The chapter will further present the results of the spatial analysis for the Local Moran's I and the Local G for the overall age sex standardised TB notification and death rates which will be followed by the results of the age sex standardised TB notification and death rates (male and female). Results of the mapping of the SAMPI, HIV, and spatial dependency will be presented; followed by a chapter summary. Similar to the previous chapter, the hypothesis for analysis was: There is geographical variation in TB notification and death rates across South Africa.

5.1 Completeness of the date of birth for the ETR data

Spatial analysis of the completeness of the date of birth for the ETR data was conducted to establish if there could be any association between the quality of this variable and the location of the TB hotspots. Date of birth was chosen because it had very low levels of completeness than other ETR variables. Results showed that there were 13 district municipalities that had a high percentage of records (more than half) missing a date of birth (57.6-96.1%). These district municipalities were spread across the country in eThekwini metropolitan, uThukela, John Taolo Gaetsewe, Fezile Dabi, Mangaung metropolitan, Xhariep, Lejweleputswa, Gert Sibande, Nkangala, Ehlanzeni, Greater Sekhukhune, Bohlabela, and Capricorn (see Figure 5.2).

Figure 5.1: *South African Map Showing Names of District Municipalities*

Figure 5.2: *Completeness of Date of Birth by District Municipality 2005-2012*
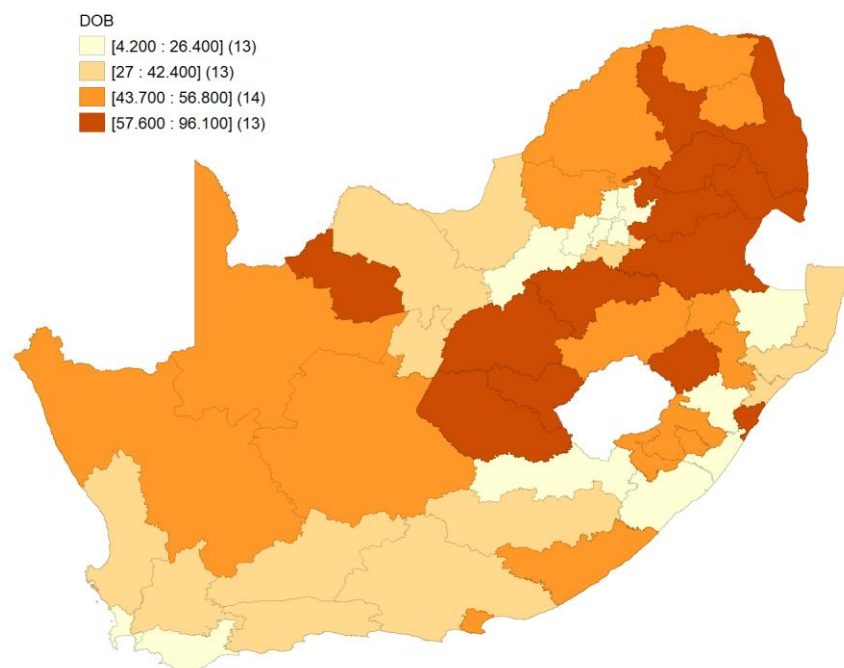
5.2 Completeness of the smoking status for the deceased for the TB mortality data

The evaluation of completeness of the TB death data revealed that the completeness of the smoking status for the deceased was low. Furthermore, smoking has been identified as a risk factor for TB; therefore, the quality of this variable is important to identify those that were smokers and died of TB. This study revealed that there were 13 district municipalities that had more than half of the records missing the smoking status variable of the deceased (57-84.6%). The district municipalities were uMgungundlovu, uThungulu, Nelson Mandela metropolitan, Ngaka Modiri Molema, Dr Kenneth Kaunda, Central Karoo, Cacadu, Overberg, Eden, City of Cape Town metropolitan, Cape Winelands, Ekurhuleni, and Johannesburg metropolitans (see Figure 5.3).

Figure 5.3: *Completeness of Smoking Status of the Deceased by District Municipality, 2005-2015*
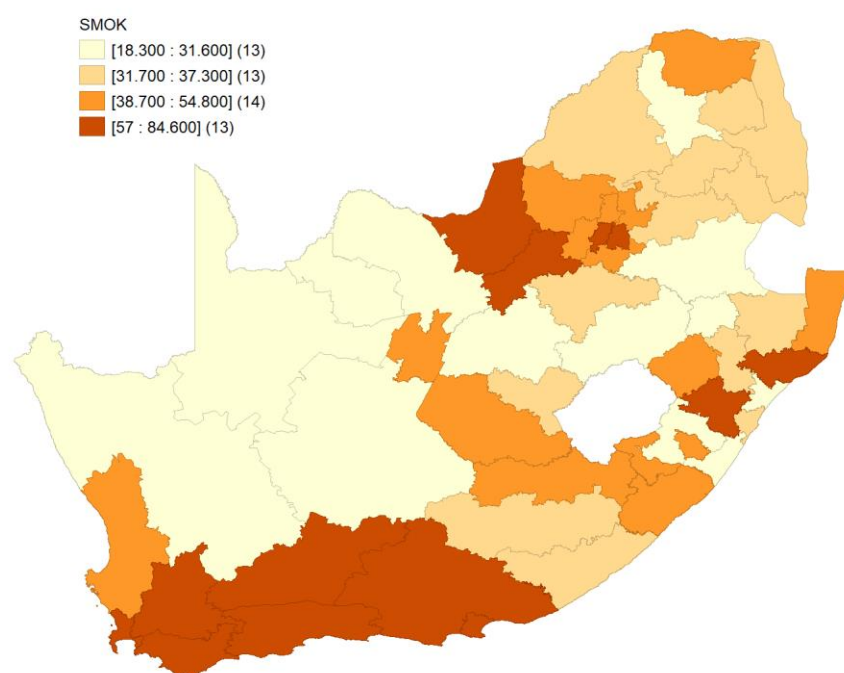
5.3 Unadjusted TB notification rates for the district municipalities for 2005

In 2005, the mean overall unadjusted TB notification rate for the district municipalities was 777.4 per 100 000 at 95% CI [644.3, 910.6]. Dr Kenneth Kaunda District municipality had the highest overall unadjusted TB notification rate in 2005 at 2 054.1 per 100 000 population; similarly, the same district municipality had the highest unadjusted TB notification rates for both male and female at 3 243.0 and 2 536.9 per 100 000 population, respectively. The mean

unadjusted TB notification rates for males and females were 910 per 100 000 at 95% CI [739.4, 1 082.5] and 671.2 per 100 000 at 95% CI [537.8, 805.8] respectively. The lowest overall unadjusted TB notification rates in 2005 were observed in uThukela district municipality (0.0 per 100 000 population). In 2005, Nkangala, uThukela, and uThungulu district municipalities had the lowest unadjusted TB notification rates for males (0.0 per 100 000 population); while in addition to Nkangala and uThukela district municipalities, Ehlanzeni district municipality had the lowest unadjusted TB notification rates for females (0.0 per 100 000 population) (see Table 5.15; Appendix G).

5.4 Unadjusted TB notification rates for the district municipalities for 2010

The mean overall unadjusted TB notification rate for the district municipalities in 2010 was 1 097.2 per 100 000 at 95% CI [958.8, 1 235.6]. The highest overall unadjusted TB notification rate for 2010 was observed in Ugu district municipality (2 335.2 per 100 000 population); the same district municipality that had the highest unadjusted TB notification rates for both male and female at 2 638.6 and 2 073.1 per 100 000 population, respectively. The mean unadjusted TB notification rates for males and females were 1 190 per 100 000 at 95% CI [1 040.9, 1 340.0] and 977.0 per 100 000 at 95% CI [852.2, 1 101.8] respectively. In 2010, Ekurhuleni metropolitan municipality recorded the lowest overall unadjusted TB notification rate (116.0 per 100 000 population). The same metropolitan municipality had the lowest unadjusted TB notification rates for both male and female at 119.2 and 112.5 per 100 000 population respectively (see Table 5.16; Appendix G).

5.5 Age sex standardised TB notification rates for the district municipalities for 2005

In 2005, the mean overall age sex standardised TB notification rate for the district municipalities was 956.3 per 100 000 at 95% CI [786.9, 1 125.6]. For this period, the highest overall age sex standardised TB notification rate was in Dr Kenneth Kaunda district municipality (2 902.9 per 100 0000 population). This is the same district municipality where the highest age standardised TB notification rates were observed for both male and female at 3 218.2 and 2 497.3 per 100 0000 population, respectively. The mean age sex standardised TB notification rates for males and females were 531 per 100 000 at 95% CI [438.3, 625.2] and 425.2 per 100 000 at 95% CI [348.0, 502.4] respectively. In the same year, the lowest overall age standardised TB notification rates were observed in uThungulu and uThukela district municipalities (0.0 per 100 000 population). The lowest age standardised TB notification rate for males was observed in three district municipalities—Nkangala, uThungulu, and uThukela

(0.0 per 100 000 population); while the lowest for females was observed in Ehlanzeni, uThungulu, and uThukela district municipalities (0.0 per 100 000 population) (The see Table 5.17; Appendix G).

5.6 Age sex standardised TB notification rates for the district municipalities for 2010

The mean overall age standardised TB notification rate for the district municipalities in 2010 was 1 296 per 100 000 at 95% CI [1 123.2, 1 468.7]. uMkhanyakude district municipality had the highest overall age standardised TB notification rate (2 402.4 per 100 000 population) in 2010. Amongst males, the mean age sex standardised TB notification rate was 688.2 per 100 000 at 95% CI [599.0, 777.4], with the highest age standardised TB notification rate in 2010 also observed in uMkhanyakude district municipality (2 772.8 per 100 000 population). The mean age sex standardised TB notification rate for females was 608.2 per 100 000 at 95% CI [523.0, 693.3], and the highest age standardised TB notification rate in 2010 was observed in Ugu district municipality (2 756.2 per 100 000 population). Ekurhuleni metropolitan municipality had the lowest overall age standardised TB notification rate in 2010 (132.1 per 100 000 population). The lowest age standardised TB notification rate in 2010 for both male and female was also Ekurhuleni metropolitan municipality, 133.8 and 129.8 per 100 000 population respectively (see Table 5.18; Appendix G).

5.7 Unadjusted TB death rates for the district municipalities for 2005

The results for the overall unadjusted TB death rates for the district municipalities in 2005 had a mean of 177.2 per 100 000 at 95% CI [154.5, 200.0]. The highest overall unadjusted TB death rate was in Cacadu district municipality at 560.8 per 100 000 population. Similarly, for the same period, the same district municipality had the highest unadjusted TB death rates for both male and female at 655.5 and 469.7 per 100 000 population, respectively. The mean unadjusted TB death rates for males and females were 204.1 per 100 000 at 95% CI [173.8, 234.4] and 156.3 per 100 000 at 95% CI [133.0, 179.6] respectively. Vhembe district municipality recorded the lowest overall unadjusted TB death rate for 2005 (50.6 per 100 000 population). Likewise, in 2005, Vhembe district municipality observed the lowest TB death rates for both male and female at 64.9 and 39.1 per 100 000 population respectively (See Table 5.19; Appendix G).

5.8 Unadjusted TB death rates for the district municipalities for 2010

The mean overall unadjusted TB death rates for the district municipalities in 2010 was 163.8 per 100 000 at 95% CI [142.9, 184.8]. In 2010, the results for the overall unadjusted TB death rates were highest in Xhariep district municipality at 365.7 per 100 000 population. For the same period, Ugu district municipality had the highest unadjusted TB death rates for males at 424.1 per 100 000 population. The mean unadjusted TB death rate for males in 2010 was 193.7 per 100 000 at 95% CI [168.7, 218.7]. Similar to the overall unadjusted TB death rates, Xhariep district municipality had the highest unadjusted TB death rate for females (328.7 per 100 000 population). The mean unadjusted TB death rate for females in 2010 was 141.4 per 100 000 at 95% CI [122.7, 160.0]. The lowest overall unadjusted TB death rate in 2010 was observed in Vhembe district municipality (56.4 per 100 000 population). Johannesburg metropolitan municipality had the lowest TB death rate for males (70.5 per 100 000 population) whereas Vhembe district municipality recorded the lowest TB death rate for females at 49.3 per 100 000 population in 2010 (See Table 5.20; Appendix G).

5.9 Age sex standardised TB death rates for the district municipalities for 2005

In 2005, the mean overall age standardised TB death rate for the district municipalities was 231.4 per 100 000 at 95% CI [198.7, 264.0]. The highest overall age standardised TB death rate in 2005 was observed in uMzinyathi district municipality at 546.1 per 100 000 population. Similarly, for both males and females, uMzinyathi district municipality had the highest age sex standardised TB death rates at 734.7 and 423.4 per 100 000 population, respectively. The mean age sex standardised TB death rates for males and females were 120.3 per 100 000 at 95% CI [102.6, 138.0] and 108.2 per 100 000 at 95% CI [92.4, 124.0] respectively. In 2005, the lowest overall age sex standardised TB death rate was in Cape Town metropolitan municipality (61.1 per 100 000 population); the same metropolitan municipality that had the lowest age sex standardised TB death rates for both males and females at 75.8 and 47.0 per 100 000 population respectively (see Table 5.21; Appendix G).

5.10 Age sex standardised TB death rates for the district municipalities for 2010

The mean overall age sex standardised TB death rate for the district municipalities in 2010 was 209.5 per 100 000 at 95% CI [179.4, 240.0]. In 2010, Ugu district municipality had the highest overall age sex standardised TB death rate (516.0 per 100 000 population). During 2010, for both males and females, the highest observed age sex standardised TB death rates were also in

Ugu district municipality at 615.0 and 438.4 per 100 000 population, respectively. For this period, the mean age sex standardised TB death rates for males and females were 115.6 per 100 000 at 95% CI [99.7, 131.5] and 93.8 per 100 000 at 95% CI [79.5, 108.2] respectively. Namakwa district municipality recorded the lowest overall age sex standardised TB death rate in 2010 (69.9 per 100 000 population). Johannesburg metropolitan municipality had the lowest age sex standardised TB death rate in 2010 for males (77.5 per 100 0000 population), whereas, Namakwa district municipality recorded the lowest age sex standardised TB death rate for females (55.7 per 100 000 population) (see Table 5.22; Appendix G).

5.11 Spatial autocorrelation

Results of the spatial autocorrelation from the Global Moran's I are presented in this section. The overall results will be presented first, for both unadjusted and age sex standardised TB notification rates for the study periods 2005 and 2010. These will be followed by the unadjusted TB notification rates for males and females for the same study period. After these, the age sex standardised TB notification rates for males and females will follow. Finally, the results for TB death rates will be presented (overall unadjusted and age sex standardised, unadjusted and sex age standardised for males and females) for 2005 and 2010.

5.11.1 Spatial autocorrelation for the overall unadjusted TB notification rates for 2005 and 2010

Table 5.1 shows results for the Global Moran's I for the overall unadjusted TB notification rates for 2005 and 2010. The results for both 2005 and 2010 revealed that spatial autocorrelation existed because the two Global Moran's I values were more than zero, and both the Z-values were positive and significant at 99% confidence. Therefore, these results show that there was greater similarity in the unadjusted TB notification rates between a district municipality and its neighbouring district municipalities for both 2005 and 2010. These results mean that those districts municipalities with high values of the overall unadjusted TB notification rates for both 2005 and 2010 were located close to those with high rates and those with low rates were located close to those with low rates. The Global Moran's I and Z values were higher for 2010 than 2005. These high values for 2010, mean that there was a greater similarity between the neighbouring district municipalities coupled with a high intensity of clustering for the overall unadjusted TB notification rates in 2010 than in 2005.

Table 5.1: *Global Moran's Indices, Z and P-Values for the Overall Unadjusted Tuberculosis notification Rates, 2005 and 2010*

Variable	Year	Moran's I	Z value	p-value	99% CI
Overall	2005	0.227	3.085	0.01	(0.142, 0.391)
unadjusted TB	2010	0.488	5.041	0.01	(0.323, 0.652)
notification rates					

Note: Significant at 99% confidence

5.11.2 Spatial autocorrelation for the overall age sex standardised TB notification rates for 2005 and 2010

Results of the Global Moran's I for the age sex standardised TB notification rates for 2005 and 2010 showed that there was spatial autocorrelation in the TB data. For both years, the Global Moran's I values were positive and more than zero which was similar to the Z values. These were significant at 99% confidence for 2010 and not for 2005. These results demonstrate that there was a higher level of similarity in the age sex standardised TB notification rates between a district municipality and any neighbouring district municipality for both 2005 and 2010. Both the Global Moran's I and Z values for 2010 were higher than those of 2005. This means that there was a higher level of similarity between any neighbouring district municipality and a higher level of intensity of clustering in 2010 than in 2005 (See Table 5.2).

Table 5.2: *Global Moran's Indices, Z and P-Values for the Overall Age Sex Standardised Tuberculosis Notification Rates, 2005 and 2010*

Variable	Year	Moran's I	Z value	p-value	99% CI
Overall age sex	2005	0.105	1.211	0.120	(0.073, 0.282)
standardised TB	2010	0.556	7.003	0.010	(0.369, 0.743)
notification rates					

Note: Significant at 99% confidence

5.11.3 Spatial autocorrelation for unadjusted TB notification rates for male and female 2005 and 2010

The results of the Global Moran's I values for the unadjusted TB notification rates for males and females, 2005 and 2010, were both positive and greater than one. The Z values for the same period were positive and greater than one and, moreover, they were significant at 99% confidence. These results mean that there was auto correlation for the unadjusted TB notification rates for both male and female for the periods 2005 and 2010. Furthermore, these results mean that the unadjusted TB notification rates for males and females in 2005 and 2010

were similar between a district municipality and those district municipalities that were next to it. The Moran's I and Z values for 2005, for both male and female, were lower than those of 2010, for both male and female; meaning there was a higher level of similarity between neighbouring district municipalities together with a high level of intensity of clustering for the unadjusted TB notification rates in 2010 than in 2005 (see Table 5.3).

Table 5.3: *Global Moran's Indices, Z and P-Values for Unadjusted Tuberculosis Notification Rates by Sex, 2005 and 2010*

Sex	Year	Moran's I	Z value	p-value	99% CI
Male	2005	0.219	2.276	0.03	(0.045, 0.392)
	2010	0.488	5.424	0.01	(0.287, 0.688)
Female	2005	0.173	2.540	0.01	(0.013, 0.359)
	2010	0.485	5.449	0.01	(0.322, 0.647)

Note: Significant at 99% confidence

5.11.4 Spatial autocorrelation for age sex standardised TB notification rates for male and female for 2005 and 2010

Results of the Global Moran's I for the age sex standardised TB notification rates for both male and female revealed an existence of spatial autocorrelation in the 2005 and 2010 TB data. This is because all the Global Moran's I values were more than zero with all having positive Z-values that were significant at 99% confidence. This means that there was greater similarity observed between a district municipality for the age sex standardised TB notification rates and its neighbouring district municipalities. Therefore, those district municipalities with high values of age sex standardised TB notification rates for both 2005 and 2010 were located close to those with high rates and those with low rates were located close to those with low rates. However, the Global Moran's I and Z-values were higher for both male and female in 2010 than 2005. These high values are indicative of a high level of similarity between neighbouring district municipalities coupled with a high level of intensity of clustering for the age sex standardised TB notification rates in 2010 than in 2005 (see Table 5.4).

Table 5.4: *Global Moran's Indices and Z Values for Age Sex Standardised Tuberculosis Notification Rates by Sex, 2005 and 2010*

Sex	Year	Moran's I	Z value	p-value	99% CI
Male	2005	0.111	1.54	0.070	(0.069, 0.290)
	2010	0.559	6.22	0.001	(0.379, 0.739)
Female	2005	0.112	1.43	0.070	(0.056, 0.279)
	2010	0.446	5.23	0.001	(0.263,0.630)

Note: Significant at 99% confidence

5.11.5 Spatial autocorrelation for the overall unadjusted TB death rates for 2005 and 2010

Results for the Moran's I and the Z values for the overall unadjusted TB death rates for 2005 and 2010 were positive and greater than one. The results were significant at 99% confidence. These results revealed that there was autocorrelation for the overall unadjusted TB death rates for both 2005 and 2010, which means that there was a higher level of similarity between a district municipality for the overall unadjusted TB death rates and its neighbouring district municipalities. The Moran's I and Z values were higher for 2005 than for 2010 which meant that there was a higher level of similarity between those district municipalities that were next each other in addition to a higher level of intensity of clustering for the overall unadjusted TB death rates in 2005 than in 2010 (see Table 5.5).

Table 5.5: *Global Moran's Indices, Z and P-Values for the Overall Unadjusted Tuberculosis Death Rates, 2005 and 2010*

Variable	Year	Moran's I	Z value	p-value	99% CI
Overall unadjusted TB death rates	2005	0.427	5.084	0.010	(0.248, 0.605)
	2010	0.367	4.239	0.010	(0.187, 0.547)

Note: Significant at 99% confidence

5.11.6 Spatial autocorrelation for the overall age sex standardised TB death rates for 2005 and 2010

In 2005 and 2010, results for both the Moran's I and Z values were positive and greater than zero for the overall age sex standardised TB death rates. In addition, the results were significant at 99% confidence. These results are indicative of a presence of autocorrelation for the overall age sex standardised TB death rates for 2005 and 2010. Therefore, there was significant similarity between district municipalities for the overall age sex standardised TB death rates

and those district municipalities next to it for the periods 2005 and 2010. Furthermore, results revealed that both the Moran's I and Z values were higher for 2005 than for 2010; hence, there was a greater similarity between those district municipalities that were next to each other in addition to a higher intensity of clustering for the overall age sex standardised TB death rates in 2005 than in 2010 (see Table 5.6).

Table 5.6: *Global Moran's Indices, Z and P-Values for the Overall Age Sex Standardised Tuberculosis Death Rates, 2005 and 2010*

Variable	Year	Moran's I	Z value	p-value	99% CI
Overall age sex standardised TB death rates	2005	0.585	6.294	0.010	(0.402, 0.767)
	2010	0.372	4.781	0.010	(0.196, 0.549)

Note: Significant at 99% confidence

5.11.7 Spatial autocorrelation for unadjusted TB death rates for male and female for 2005 and 2010

The results of the Global Moran's I for the unadjusted TB death rates for male and female in 2005 and 2010 were positive and greater than zero; similarly, the Z values were positive and all significant at 99% confidence. This means that there was spatial autocorrelation in the 2005 and 2010 unadjusted TB death rates. These results mean that there was a higher level of similarity for the unadjusted TB death rates between a district municipality and those district municipalities next to it. The 2005 Moran's I results for male (0.225) were close to those of female (0.213) for the same period; similar to the 2010 results at 0.384 and 0.374 for male and female, respectively. Therefore, the similarity between neighbouring district municipalities and the intensity of clustering for the unadjusted TB death rates for 2010 and 2005 were similar (see Table 5.7).

Table 5.7: *Global Moran's Indices and Z Values for Unadjusted Tuberculosis Death Rates by Sex, 2005 and 2010*

Sex	Year	Moran's I	Z value	p-value	99% CI
Male	2005	0.225	3.508	0.020	(0.071, 0.379)
	2010	0.384	4.303	0.010	(0.225, 0.542)
Female	2005	0.213	2.978	0.020	(0.078, 0.258)
	2010	0.374	4.144	0.010	(0.206, 0.542)

Note: Significant at 99% confidence.

5.11.8 Spatial autocorrelation for age sex standardised TB death rates for male and female for 2005 and 2010

The Global Moran's I results of the age sex standardised TB death rates for male and female in 2005 and 2010 were positive and greater than zero; similarly, the results for the Z values were also positive. All these results were significant at 99% confidence. This means that autocorrelation existed for both male and female in the 2005 and 2010 age sex standardised TB death rates. Furthermore, these results revealed greater similarity between a district municipality and those district municipalities located next to it for the age sex standardised TB death rates for 2005 and 2010. The Global Moran's I and Z values were higher for both male and female for 2005 than for those in 2010. These high values are indicative of a higher level of similarity between those district municipalities that were next to each other and a high intensity of clustering in 2005 compared to 2010 (see Table 5.8).

Table 5.8: *Global Moran's Indices and Z Values for Age Sex Standardised Tuberculosis Death Rates by Sex, 2005 and 2010*

Sex	Year	Moran's I	Z value	p-value	99% CI
Male	2005	0.592	7.100	0.001	(0.414, 0.770)
	2010	0.431	5.000	0.001	(0.237, 0.624)
Female	2005	0.627	7.232	0.001	(0.447, 0.806)
	2010	0.377	4.385	0.002	(0.211, 0.543)

Note: Significant at 99% confidence

5.12 Crude rates box map analysis

This section presents results of the crude box map analysis. Overall crude TB notification rates box maps for 2005 and 2010 will be presented first, followed by box maps for male and then female. Next to be presented will be the overall standardised TB notification rates box maps for 2005 and 2010, followed by the male and female box maps. The next results to be presented will be the rate box maps for TB death rates. These will begin with the overall crude TB death rates box maps for both 2005 and 2010, followed by male and female results for the same period. Finally, the results of the standardised TB rates box maps will be presented starting with the overall standardised TB death rates box maps, then those for male and female for the periods 2005 and 2010.

5.12.1 Overall crude TB notification rates box mapping for 2005

According to the results of the 2005 crude rate box map analysis for the overall crude TB notifications rates, there were 11 district municipalities in the fourth quartile (Q4) (>75%

[0.011 : 0.020]), on the western, eastern, and southern part of the country. The 11 district municipalities in the fourth quartile were Ruth S Mompati (North West province); Lejweleputswa (Free State province); Zululand, uMzinyathi, iLembe, and uMgungundlovu (KwaZulu-Natal province); Cacadu and Nelson Mandela metropolitan (Eastern Cape province); and Eden, Cape Winelands, and Overberg (Western Cape province). There were 14 district municipalities in the third quartile (Q3) (50-75% [0.007 : 0.011]), while there were 13 district municipalities in the second quartile (Q2) (25-50% [0.005 : 0.007]) and another 13 in the first quartile (Q1) (< 25% [-0.004 : 0.005]). Although there were no lower outliers, this raw rate box map analysis demonstrated that there were two district municipalities, Pixley Ka Seme and Dr Kenneth Kaunda in Northern Cape and North West provinces respectively that were upper outliers [0.020 : infinity] for the overall crude TB notification rates in 2005 (see Figure 5.4).

Figure 5.4: *Crude Overall Tuberculosis Notification Rates Box Map by District Municipality, 2005*
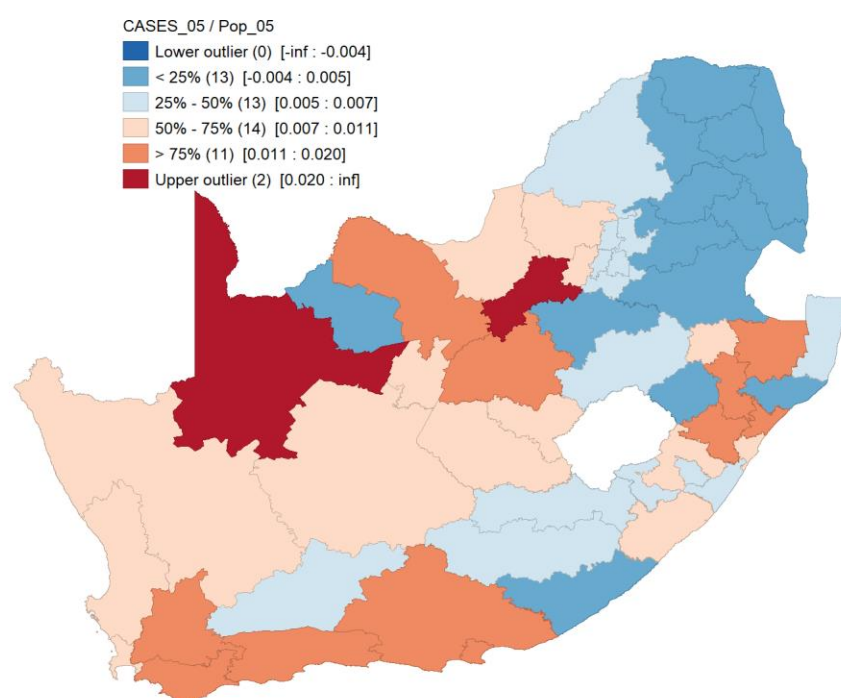
5.12.2 Overall crude TB notification rates box mapping for 2010

In 2010, the results of the raw rate box map analysis for the overall crude TB notification rates identified 13 district municipalities in Q4 (>75% [0.014 : 0.025]). These district municipalities (Siyanda, Ruth S Mompati, Dr Kenneth Kaunda, Cacadu, uMkhanyakude, Zululand, Umzinyathi, uThungulu, iLembe, uMgungundlovu, eThekwini, Ugu, and Sisonke) were on the

eastern and western side of South Africa. Another 14 district municipalities were identified in Q3 (50-75% [0.012 : 0.014]), a further 13 district municipalities were in Q2 (25-50% [0.006 : 0.012]), and another 13 were in Q1 (< 25% [-0.005 : 0.006]). However, analysis did not identify any district municipalities that were either lower or upper outliers for the overall crude TB notification rates in 2010 (see Figure 5.5).

Figure 5.5: *Crude Overall Tuberculosis Notification Rates Box Map by District Municipality, 2010*
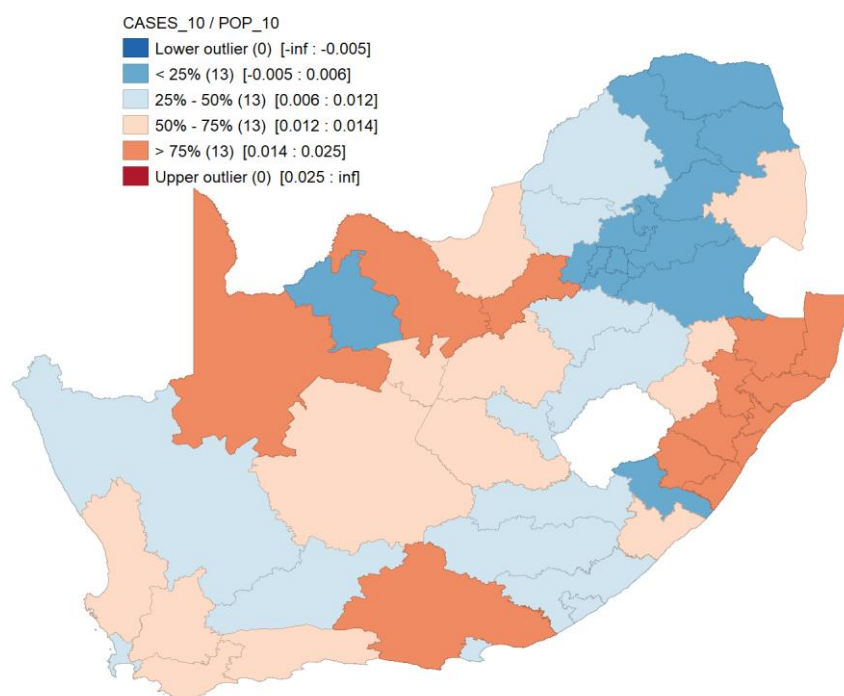
5.12.3 Crude TB notification rates box mapping for male in 2005

The results of the raw rate box map analysis for the crude TB notification rates for the male in 2005 revealed 11 district municipalities (Siyanda, West Coast, Cape Winelands, Overberg, Eden, Cacadu, Nelson Mandela metropolitan, Lejweleputswa, Umzinyathi, iLembe, and uMgungundlovu) in Q4 (>75% [0.013 : 0.023]) on the eastern, western, and southern parts of the country. Fourteen district municipalities were in Q3 (50-75% [0.008 : 0.013]), 13 in Q2 (25-50% [0.006 : 0.008]), and 13 in Q1 (< 25% [-0.005 : 0.006]). Furthermore, results did not identify any district municipalities that were lower outliers; however, there were two district municipalities (Pixley Ka Seme and Dr Kenneth Kaunda) that were identified as upper outliers [0.023 : infinity] (see Figure 5.6).

Figure 5.6: *Crude Tuberculosis Notification Rates Box Map by District Municipality and Male, 2005*
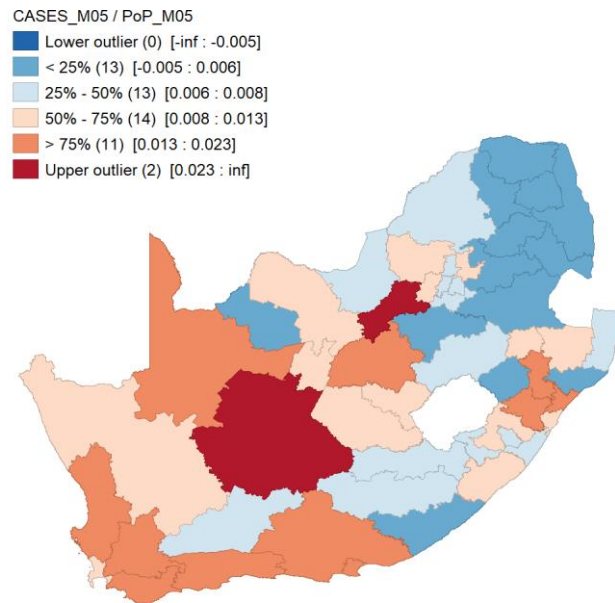
5.12.4 Crude TB notification rates box mapping for male in 2010

Twelve district municipalities were identified in Q4 (>75% [0.015 : 0.026]) by the raw rate box map analysis for the crude male TB notifications in 2010; these were Siyanda (Northern Cape province); Ruth S Mompati and Dr Kenneth Kaunda (North West province); Lejweleputswa (Free State province); Cacadu (Eastern Cape province); and uMkhanyakude, Umzinyathi, uThungulu, iLembe, uMgungundlovu, eThekwini, and Sisonke (KwaZulu-Natal province). The results further revealed that there were 14 district municipalities in Q3 (50-75% [0.013 : 0.015]); whereas there were 13 in Q2 (25-50% [0.007 : 0.013]) and a further 13 district municipalities in Q1 (< 25% [-0.004 : 0.007]). No district municipalities that were identified as lower outliers however, there was one district municipality (Ugu) in KwaZulu-Natal province that was identified as an upper outlier [0.023 : infinity] in 2010 (see Figure 5.7).

Figure 5.7: *Crude Tuberculosis Notification Rates Box Map by District Municipality and Male, 2010*
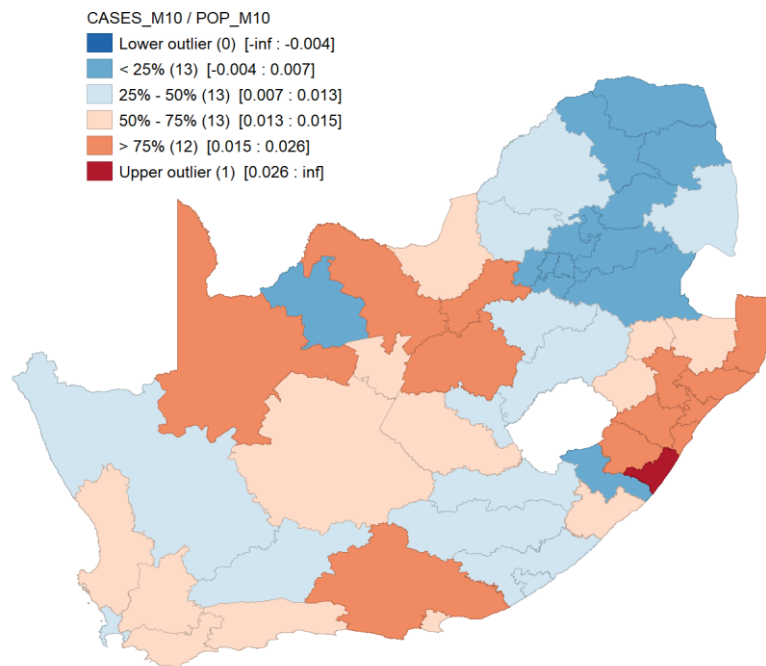
5.12.5 Crude TB notification rates box mapping for female in 2005

The results of the raw rate box map analysis for TB notifications for female in 2005 showed that 10 district municipalities were in Q4 (>75% [0.009 : 0.018]). The 10 district municipalities in the fourth quartile were Ruth S Mompati (North West province); Lejweleputswa (Free State province); Zululand, Umzinyathi, iLembe, and uMgungundlovu (KwaZulu-Natal province); Cacadu and Nelson Mandela metropolitan (Eastern Cape province); and Cape Winelands and Overberg (Western Cape province). There were 14 district municipalities in Q3 (50-75% [0.006 : 0.009]). For the other two quartiles, Q2 and Q1 there were 13 district municipalities in each, with (25-50% [0.004 : 0.006]) and (<25% [-0.005 : 0.004]) in Q2 and Q1, respectively. Furthermore, there were three district municipalities, two in Northern Cape province (Pixley Ka Seme and Siyanda) and one in North West province (Dr Kenneth Kaunda district municipality) that were upper outliers [0.018l : infinity]. For this raw box map analysis, there were no district municipalities that were identified as lower outliers (see Figure 5.8).

Figure 5.8: *Crude Tuberculosis Notification Rates Box Map by District Municipality and Female, 2005*

CASES_F05 / Pop_F05
- Lower outlier (0) [-inf : -0.005]
- < 25% (13) [-0.005 : 0.004]
- 25% - 50% (13) [0.004 : 0.006]
- 50% - 75% (14) [0.006 : 0.009]
- > 75% (10) [0.009 : 0.018]
- Upper outlier (3) [0.018 : inf]

5.12.6 Crude TB notification rates box mapping for female in 2010

There were 13 district municipalities that were identified in Q4 (>75% [0.013 : 0.023]) by the raw rate box map analysis for the crude TB notifications for female in 2010. The Q4 district municipalities were Siyanda (Northern Cape province); Ruth S Mompati and Dr Kenneth Kaunda (North West province); Xhariep (Free State province); and iLembe, uMkhanyakude, Umzinyathi, uThungulu, uMgungundlovu, eThekwini, and Sisonke (KwaZulu-Natal province). Fourteen other district municipalities were identified in Q3 (50-75% [0.010 : 0.013]); whereas there were 13 district municipalities in Q2 (25-50% [0.006 : 0.010]) and another 13 in Q1 (< 25% [-0.004 : 0.006]). In 2010, there were no district municipalities that were identified as upper or lower outliers by the raw rate box map analysis (see Figure 5.9).

5.12.7 Overall standardised TB notification rates box mapping for 2005

Results of the overall standardised TB notification rates box map analysis for 2005 demonstrated that there were 11 district municipalities in Q4 (>75% [1.595 : 2.923]), these were the same district municipalities for the overall crude TB notification rates in 2005. There were 14 district municipalities in Q3 (50-75% [1.009 : 1.595]). In addition, 13 district municipalities were identified in Q2 (25-50% [0.709 : 1.009] and another 13 were categorised as Q1 (<25% [-0.619 : 0.709]). Similar to the results of the overall crude TB notification rates box map analysis in 2005, there were no lower outliers that were identified, but two district

municipalities—Pixley Ka Seme and Dr Kenneth Kaunda in Northern Cape and North West provinces respectively—were categorised as upper outliers [2.923 : infinity] for the overall standardised TB notification rates in 2005 (see Figure 5.10).

Figure 5.9: *Crude Tuberculosis Notification Rates Box Map by District Municipality and Female, 2010*
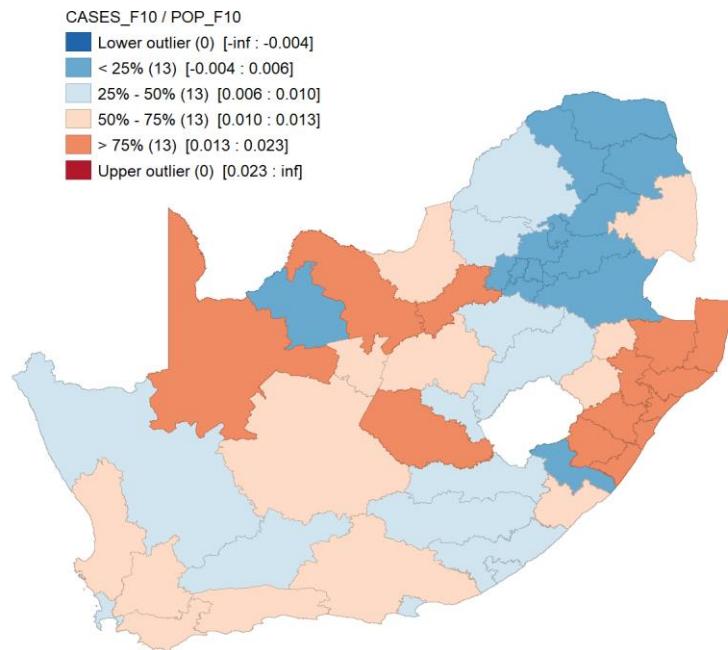
Figure 5.10: *Standardised Overall Tuberculosis Notification Rates Box Map by District Municipality, 2005*
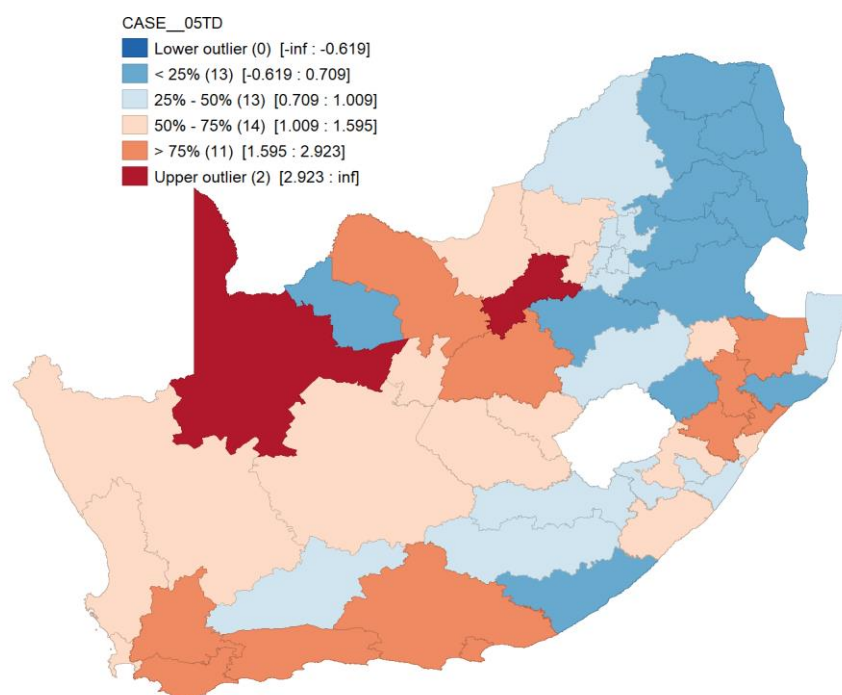
5.12.8 Overall standardised TB notification rates box mapping for 2010

Figure 5.11 shows the results of the rate box map analysis for the overall standardised TB notification rates. These results indicated that there were 13 district municipalities in Q4 (>75% [1.552 : 2.794]) and 14 in Q3 (50-75% [1.314 : 1.552]). The analysis further identified 13 district municipalities in each of the quartiles Q2 and Q1 (25-50% [0.725 : 1.314]) and (<25% [-0.517 : 0.725]) respectively. Similar to the overall crude TB notification rates box map analysis, there were no district municipalities that were either lower or upper outliers for the overall standardised TB notification rates in 2010. These results were similar to those for the overall crude TB notification rates in 2010.

Figure 5.11: *Standardised Overall Tuberculosis Notification Rates Box Map by District Municipality, 2010*
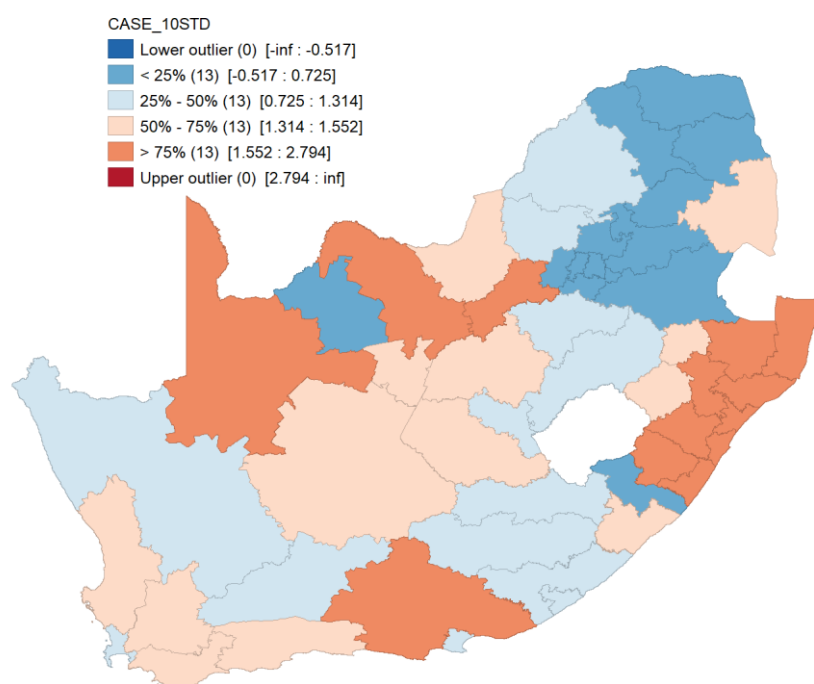
5.12.9 Standardised TB notification rates box mapping for male for 2005

The male standardised TB notification rates box map analysis for 2005 revealed that there were 11 district municipalities in Q4 (>75% [1.591 : 2.927]) and another 14 district municipalities categorised in Q3 (50-75% [1.012 : 1.591]). Thirteen other district municipalities were also identified in each of Q2 (25-50% [0.701 : 1.012] and Q1 (<25% [-0.635 : 0.701]). There were no lower outliers identified; however, in 2005 two district municipalities—Pixley Ka Seme and Dr Kenneth Kaunda in Northern Cape and North West provinces respectively—were categorised as upper outliers [2.923 : infinity] for the male standardised TB notification rates (see Figure 5.12). These findings were similar to the 2005 male crude TB notification rates.

Figure 5.12: *Standardised Tuberculosis notification rates box map by district municipality and Male, 2005*
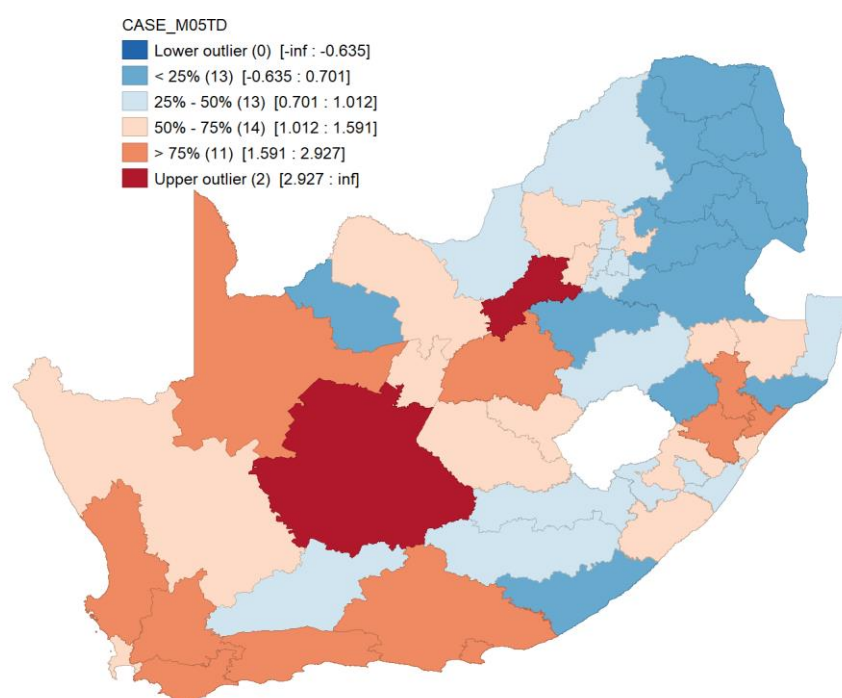
5.12.10 Standardised TB notification rates box mapping for male for 2010

The results of the rate box map analysis for the male standardised TB notification rates showed that there were 12 district municipalities in Q4 (>75% [1.545 : 2.747]) and 14 in Q3 (50-75% [1.336 : 1.545]). In Q2 and Q1 there were 13 district municipalities that were identified in each (25-50% [0.744 : 1.336]) and (<25% [-0.457 : 0.744]) respectively. Furthermore, there was one district municipality (Ugu) in KwaZulu Natal province that was identified as an upper outlier for the male standardised TB notification rates in 2010; however, there were none identified as lower outliers (see Figure 5.13). The male crude notification rates in 2010 had similar results to the standardised TB notification rates in 2010.

Figure 5.13: *Standardised Tuberculosis Notification Rates Box Map by District Municipality and Male, 2010*
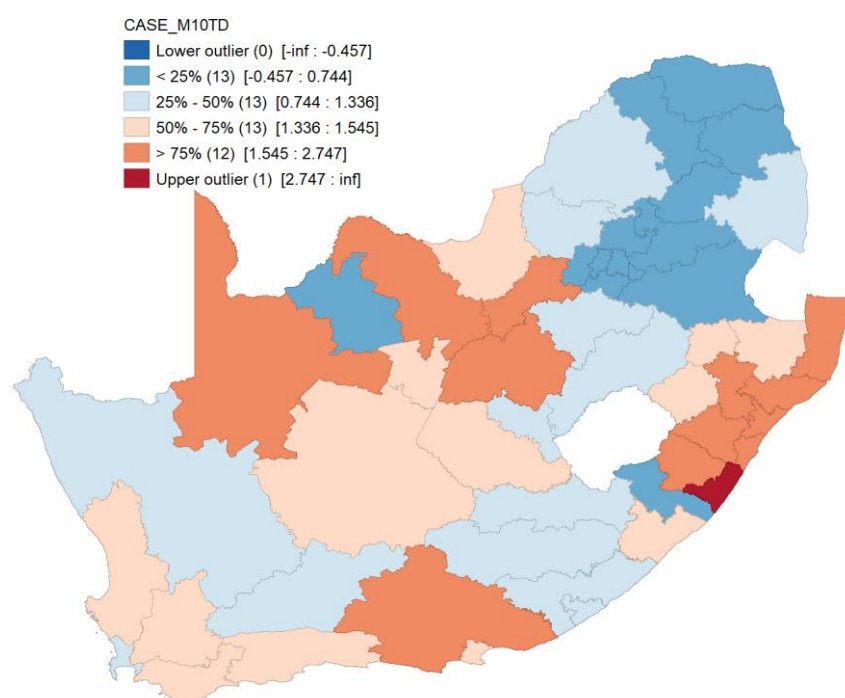
5.12.11 Standardised TB notification rates box mapping for female for 2005

In 2005, the female standardised TB notification rates box map analysis categorised 10 district municipalities to be in Q4 (>75% [1.607 : 3.060]). Another 14 were categorised in Q3 (50-75% [1.017 : 1.607]). In addition, the analysis demonstrated a presence of 13 district municipalities in each of the quartiles Q2 and Q1 (25-50% [0.638 : 1.017] and (<25% [-0.815 : 0.638]) respectively. Analysis did not identify any district municipalities as lower outliers. However, three district municipalities—Pixley Ka Seme and Siyanda in Northern Cape province and Dr Kenneth Kaunda in North West province—were categorised as upper outliers [3.060 : infinity] for the female standardised TB notification rates in 2005 (see Figure 5.14). These results revealed similar findings to those of the 2005 female crude TB notification rates.

Figure 5.14: *Standardised Tuberculosis Notification Rates Box Map by District Municipality and Female, 2005*
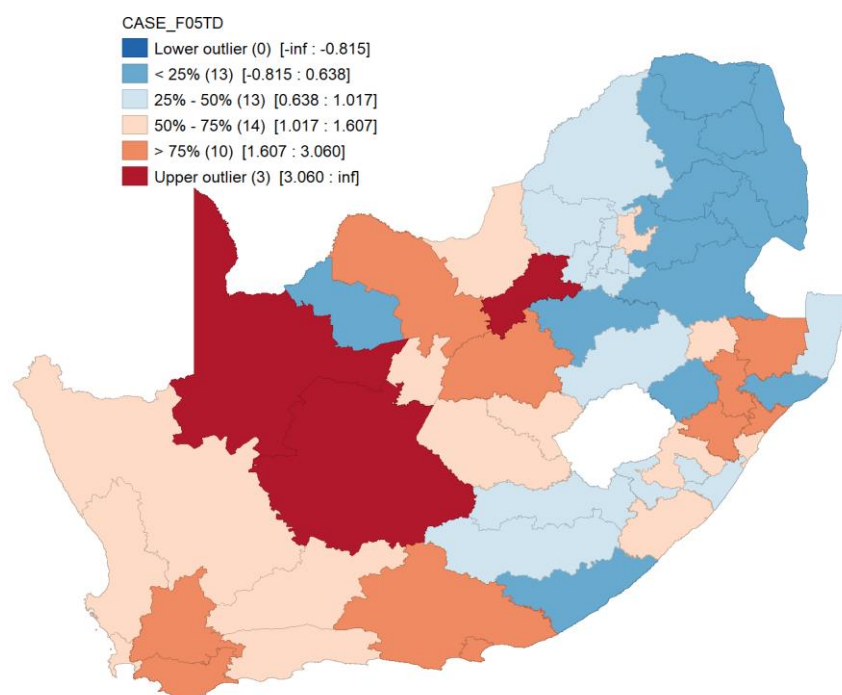
5.11.12 Standardised TB notification rates box mapping for female for 2010

According to the results of the rate box map analysis for the female standardised TB notification rates in 2010, there were 13 district municipalities in both Q4 (>75% [1.574 : 2.826]) and Q3 (50-75% [1.278 : 1.574]). Similar to 2005, in Q2 and Q1 there were 13 district municipalities identified in each (25-50% [0.738 : 1.278]) and (<25% [-0.515 : 0.738]) respectively. The results revealed that there were no district municipalities identified as upper outliers for the female standardised TB notification rates in 2010. Furthermore, the results did not classify any district municipalities as lower outliers (see Figure 5.15). Like the 2005 results, the 2010 results were similar to the 2010 results of the female crude TB notification rates.

5.13 Overall crude TB death rates box mapping for 2005

The raw rate box map analysis for the overall crude TB death rates demonstrated that there were 12 district municipalities in Q4 (>75% [0.002 : 0.004]). These were Dr Kenneth Kaunda (North West province); Frances Baard (Northern Cape province); Lejweleputswa and Xhariep (Free State province); Amathole and Nelson Mandela metropolitan (Eastern Cape province); and Amajuba, Umzinyathi, iLembe, Ugu, uThukela, and uMgungundlovu (KwaZulu-Natal province). In addition, there were 14 district municipalities in Q3 (50-75% [0.002 : 0.002]). Furthermore, the analysis identified 13 district municipalities in Q2 (25-50% [0.001 : 0.002]) as well as 13 in Q1 (<25% [-0.001 : 0.001]). The raw rate box map analysis further

demonstrated that there was one district municipality (Cacadu) in Eastern Cape province, that was an upper outlier [0.004 : infinity] for the overall crude TB death rates in 2005. However, the analysis did not identify any district municipalities as lower outliers (see Figure 5.16).

Figure 5.15: *Standardised Tuberculosis Notification Rates Box Map by District Municipality and Female, 2010*
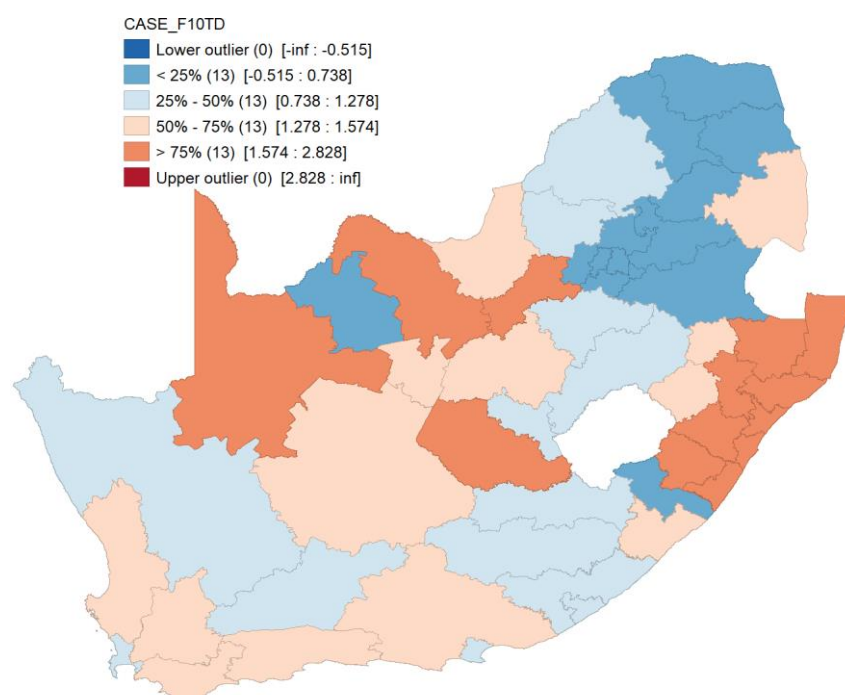
5.13.1 Overall crude TB death rates box mapping for 2010
For 2010, 13 district municipalities were identified in Q4 (>75% [0.002 : 0.004]) by the raw rate box map analysis for the overall crude TB death rates. These district municipalities (Ruth S Mompati, Pixley Ka Seme, Lejweleputswa, Xhariep, Joe Gqabi, Chris Hani, Ugu, Sisonke, uThukela, Umzinyathi, uThungulu, Zululand, and uMkhanyakude) are in North West, Northern Cape, Free State, and KwaZulu-Natal provinces. Another 14 district municipalities were in Q3 (50-75% [0.002 : 0.002]). The analysis further demonstrated that 13 district municipalities were in Q2 (25-50% [0.001 : 0.002]) and another 13 were in Q1 (<25% [-0.001 : 0.001]). However, the analysis did not identify any district municipalities as lower or higher outliers for the overall crude TB death rates in 2010 (see Figure 5.17).

**Figure 5.16:** *Crude Overall Tuberculosis Death Rates Box Map by District Municipality, 2005*
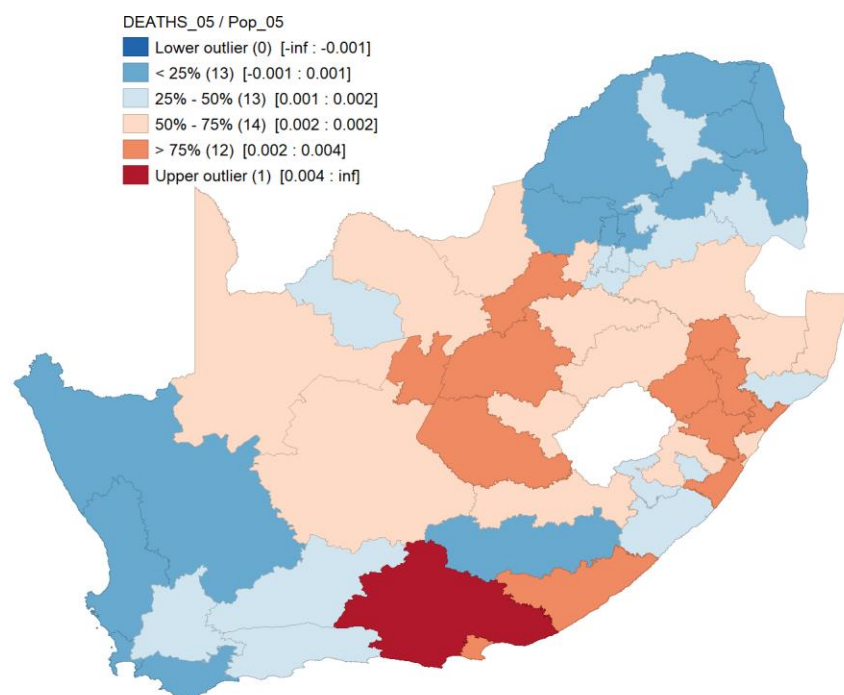
**Figure 5.17:** *Crude Overall Tuberculosis Death Rates Box Map by District Municipality, 2010*
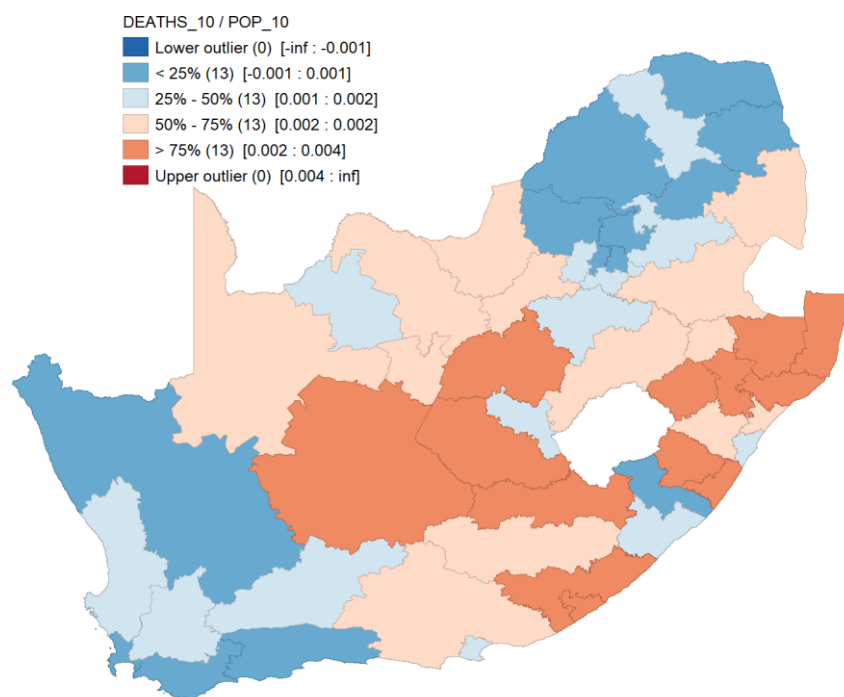
5.13.2 Crude TB death rates box mapping for male in 2005

Figure 5.18 shows that in 2005, 10 district municipalities were identified in Q4 (>75% [0.013 : 0.025]) by the raw rate box map analysis for the male crude TB death rates. These 10 district municipalities were Siyanda in Northern Cape province; Lejweleputswa in Free State province; West Coast, Cape Winelands, Overberg, and Eden in Western Cape province; Nelson Mandela metropolitan in Eastern Cape province; and Umzinyathi, uMgungundlovu, and iLembe in KwaZulu-Natal province. In addition, there were 14 district municipalities in Q3 (50-75% [0.008 : 0.013]). The analysis further identified 13 district municipalities in Q2 (25-50% [0.006 : 0.008]) and another 13 in Q1 (<25% [-0.006 : 0.006]). Furthermore, the analysis identified three district municipalities (Pixley Ka Seme, Dr Kenneth Kaunda, and Metsweding) in Northern Cape, North West, and Gauteng provinces respectively, as upper outliers ([0.025 : infinity]) for the male crude TB death rates in 2005. However, no district municipalities were identified as lower outliers.

Figure 5.18: *Crude Tuberculosis Death Rates Box Map by District Municipality and Male, 2005*
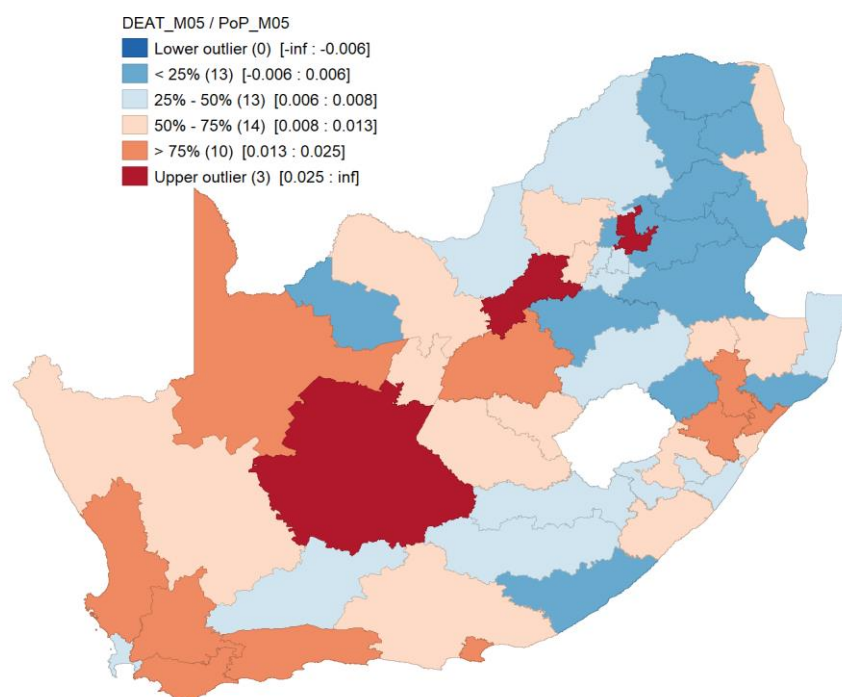
5.13.3 Crude TB death rates box mapping for male in 2010

Results of the raw rate box map analysis for the male crude TB death rates in 2010, revealed 13 district municipalities (Siyanda, Pixley ka Seme, Xhariep, Lejweleputswa, Ruth S Mompati, Buffalo City, Cacadu, uMkhanyakude, uThungulu, Umzinyathi, uMgungundlovu, Ugu, and Sisonke) in Q4 (>75% [0.002 : 0.004]). These district municipalities were in five provinces—

Free State, North West, Northern Cape, Eastern Cape, and KwaZulu-Natal. Another 13 district municipalities were in Q3 (50-75% [0.002 : 0.003]). Furthermore, 13 district municipalities were identified in Q2 (25-50% [0.001 : 0.002]) and a further 13 in Q1 (<25% [-0.005 : 0.002]). In addition, the analysis did not identify any district municipalities as upper or lower outliers for the male crude TB death rates in 2010 (see Figure 5.19).

**Figure 5.19:** *Crude Tuberculosis Death Rates Box Map by District Municipality and Male, 2010*
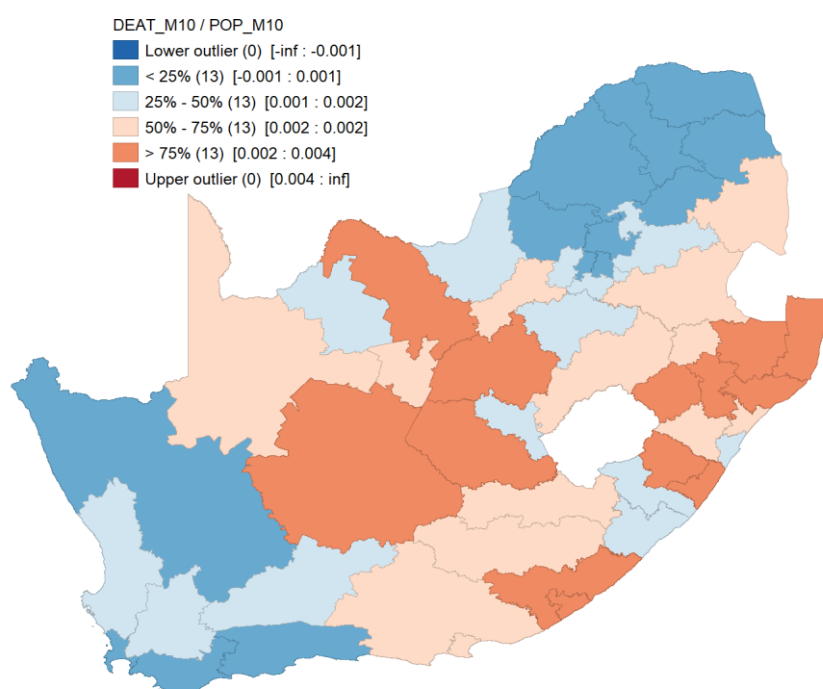
5.13.4 Crude TB death rates box mapping for female in 2005

During 2005, the raw rate box map analysis for the female crude TB death rates identified 10 district municipalities across the country in Q4 (>75% [0.010 : 0.019]). The district municipalities were Siyanda (Northern Cape province); Ruth S Mompati (North West province); Overberg and Eden (Western Cape province); Nelson Mandela metropolitan (Eastern Cape province); Bohlabela (Limpopo province); and Umzinyathi, iLembe, Zululand, and uMgungundlovu (KwaZulu-Natal province). There were 14 in Q3 (50-75% [0.006 : 0.010]). Results of the analysis further identified 13 district municipalities in Q2 (25-50% [0.004 : 0.006]), while another 13 were identified as being in Q1 (<25% [-0.005 : 0.004]). Furthermore, analysis identified three district municipalities (Metsweding, Pixley Ka Seme, and Dr Kenneth Kaunda) in Gauteng, Northern Cape, and North West provinces, respectively, as upper outliers ([0.019 : Infinity]) for the female crude TB death rates in 2005. The analysis did not categorise any district municipalities as lower outliers (see Figure 5.20).
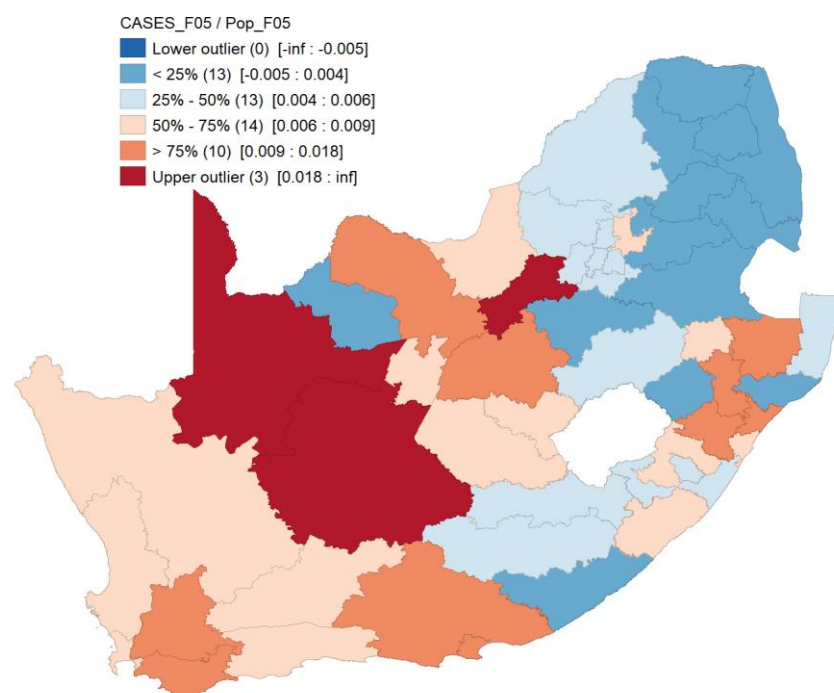
Figure 5.20: *Crude Tuberculosis Death Rates Box Map by District Municipality and Female, 2005*
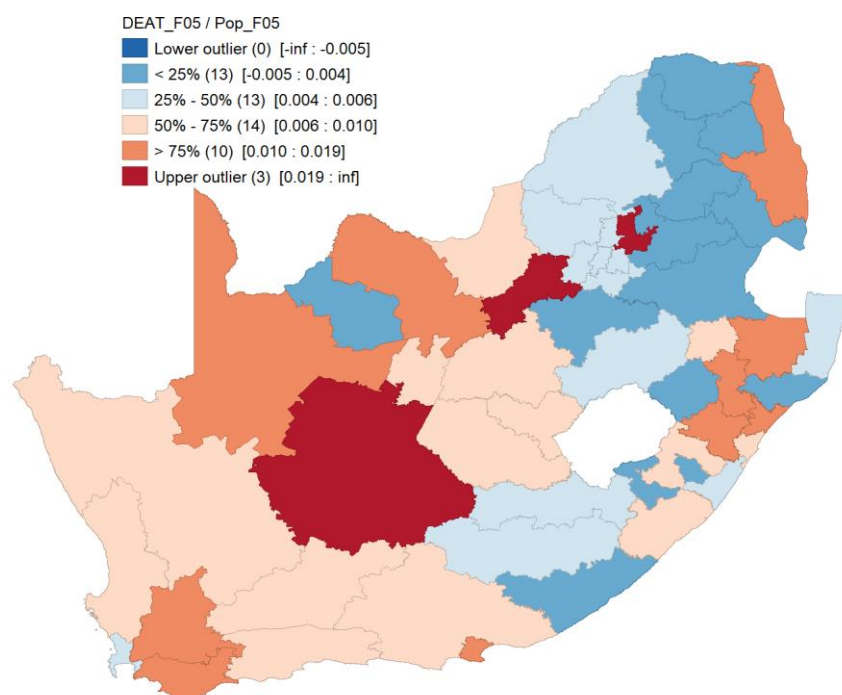
5.13.5 Crude TB death rates box mapping for female in 2010

The results of the raw rate box map analysis for the female crude TB death rates in 2010, demonstrated 13 district municipalities (Lejweleputswa, Xhariep, Pixley ka Seme, Cacadu, Amathole, Buffalo City, Joe Gqabi, Zululand, uThungulu, uThukela, Umzinyathi, Ugu, and Sisonke) in Q4 (>75% [0.002 : 0.003]). These district municipalities were mainly in the central and eastern parts of the country. There were 13 others in Q3 (50-75% [0.001 : 0.002]); a further 13 district municipalities were identified in Q2 (25-50% [0.001 : 0.001]), and another 13 in Q1 (<25% [-0.001 : 0.001]). There were no upper or lower outliers identified for the female crude TB death rates in 2010 (see Figure 5.21).

Figure 5.21: *Crude Tuberculosis Death Rates Box Map by District Municipality and Female, 2010*
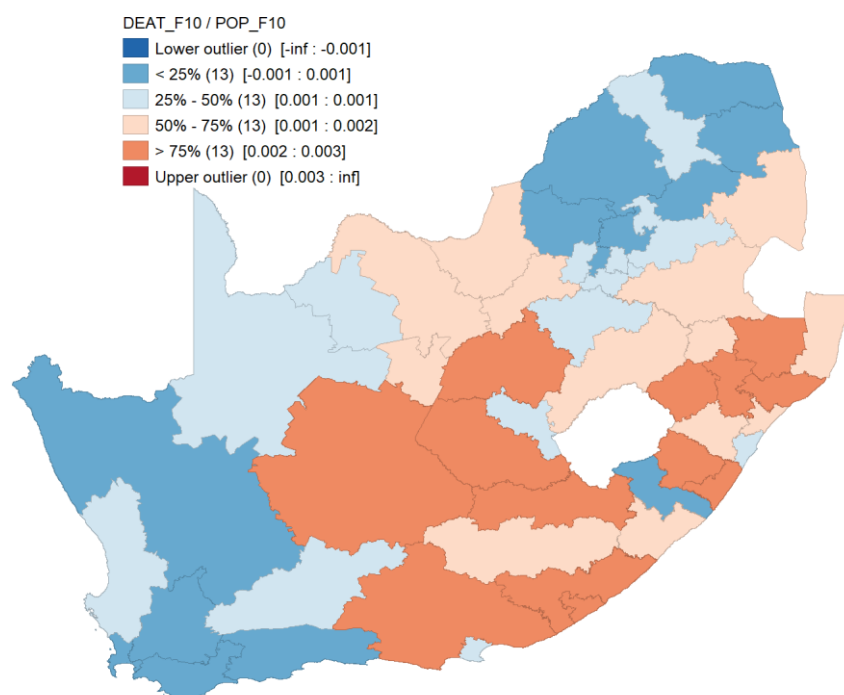
5.13.6 Overall standardised TB death rates box mapping for 2005

In 2005, the raw rate box map analysis for the overall standardised TB death rates demonstrated that there were 12 district municipalities in Q4 (>75% [1.500 : 2.825]) and another 14 in Q3 (50-75% [1.090 : 1.500]). As for Q2 and Q1, the analysis identified 13 district municipalities in each (25-50% [0.598 : 1.090]) and (<25% [-0.754 : 0.598]). Similar to the findings of the overall crude TB death rates, one district municipality (Cacadu) in Eastern Cape province was identified as an upper outlier [2.852 : infinity] for the overall standardised TB death rates in 2005. Analysis did not classify any district municipalities as lower outliers (see Figure 5.22). Results of the overall standardised TB death rates of 2005 were similar to those of the 2005 overall crude TB death rates.

Figure 5.22: *Standardised Overall Tuberculosis Death Rates Box Map by District Municipality, 2005*
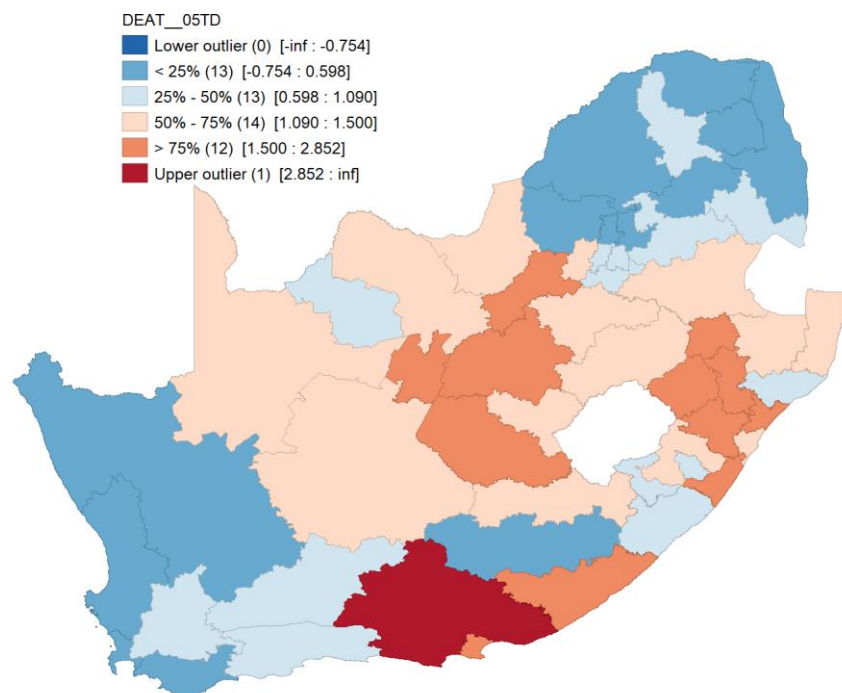
5.13.7 Overall standardised TB death rates box mapping for 2010

The results of the overall standardised TB death rates box map analysis for 2010, identified 13 district municipalities in Q4 (>75% [1.538 : 2.799]) and another 13 in Q3 (50-75% [1.126 : 1.538]). Analysis further demonstrated that Q2 and Q1 each had 13 district municipalities (25-50% [0.712 : 0.126]) and (<25% [-0.529 : 0.712]) respectively. There were neither any district municipalities that were classified as lower outliers nor higher outliers for the overall standardised TB death rates in 2010 (see Figure 5.23). These results showed a similar trend to those of the overall crude TB death rates of 2010.

5.13.8 Standardised TB death rates box mapping for male for 2005

Shown in Figure 5.24 are results of the male standardised TB death rates box map analysis for 2005, which indicated that 10 district municipalities were in Q4 (>75% [1.597 : 2.985]) and 14 district municipalities in Q3 (50-75% [0.987 : 1.597]). Q2 and Q1 each had 13 district municipalities (25-50% [0.672 : 0.987]) and (<25% [-0.716 : 0.672]) respectively. In addition, the analysis identified three district municipalities (Pixley Ka Seme, Dr Kenneth Kaunda, and Metsweding) in Northern Cape, North West, and Gauteng provinces respectively as upper outliers ([2.985 : infinity]) for the male standardised TB deaths rates in 2005. For this analysis,

no district municipalities were identified as lower outliers for the male standardised TB death rates in 2005. These findings were similar to those of the male crude TB death rates for 2005.

Figure 5.23: *Standardised Overall Tuberculosis Death Rates Box Map by District Municipality, 2010*
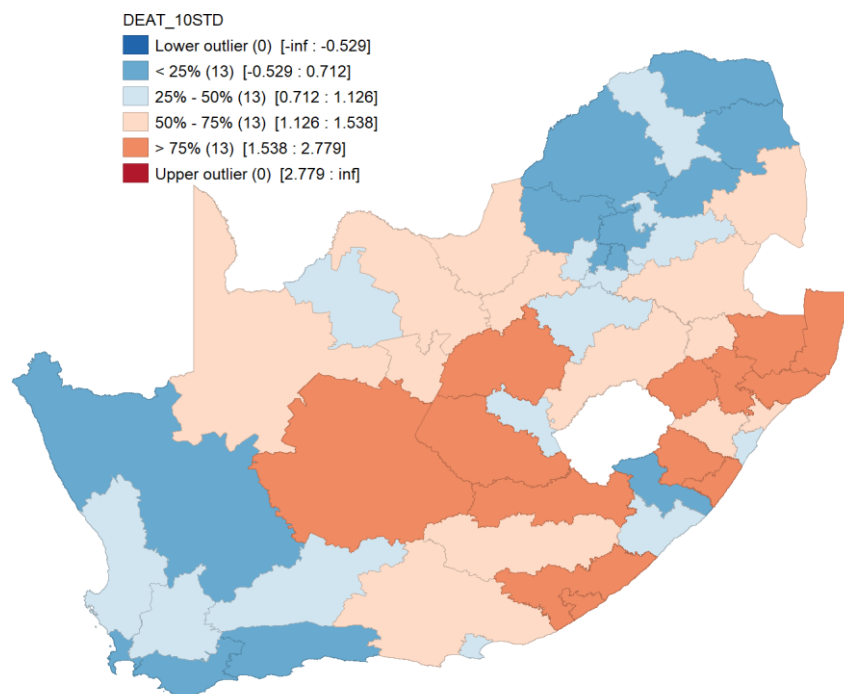
Figure 5.24: *Standardised Tuberculosis Death Rates Box Map by District Municipality and Male, 2005*
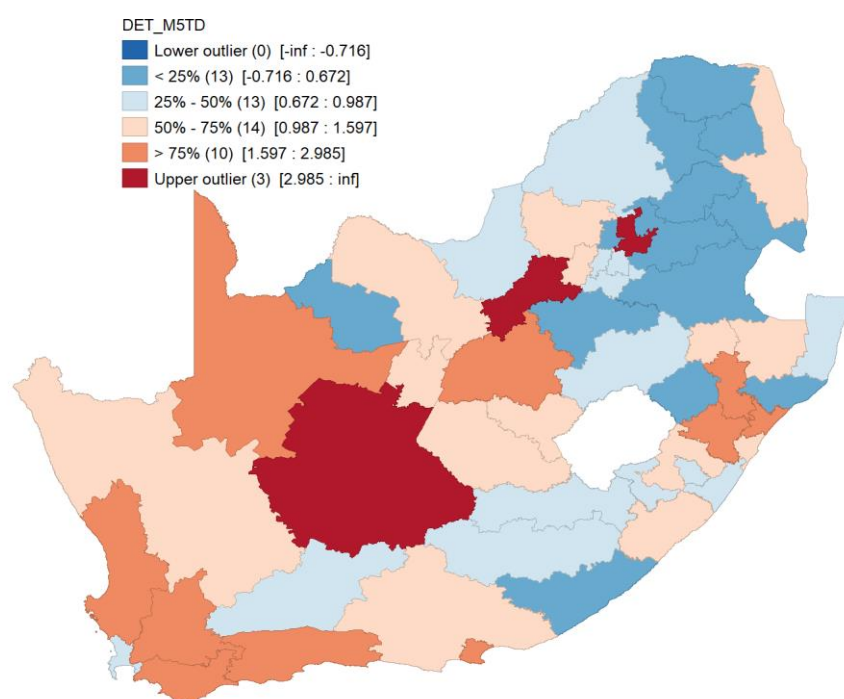
5.13.9 Standardised TB death rates box mapping for male for 2010

The results of the male standardised TB death rates box map analysis for 2010 are shown in Figure 5.25. These results revealed 13 district municipalities in Q4 (>75% [1.546 : 2.765]) with another 13 in Q3 (50-75% [1.166 : 1.546]). Similar to the results of 2005, Q2 and Q1 each had 13 district municipalities (25-50% [0.734 : 1.166]) and (<25% [-0.484 : 0.734]) respectively. There were no district municipalities identified as either upper or lower outliers. These results of the 2010 male standardised TB death rates were the same as the 2010 male crude TB death rates.

Figure 5.25: *Standardised Tuberculosis Death Rates Box Map by District Municipality and Male, 2010*
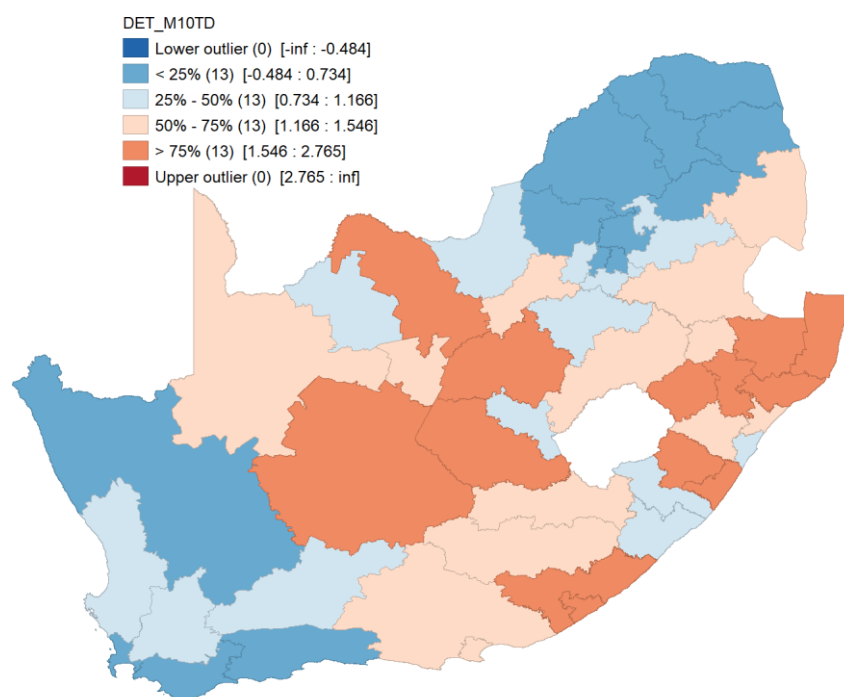
5.13.10 Standardised TB death rates box mapping for female for 2005

In 2005, the results of the box map analysis for the female standardised TB death rates identified 10 district municipalities in Q4 (>75% [1.632 : 3.084]) and 14 in Q3 (50-75% [0.984 : 1.632]). Results of the analysis further identified 13 district municipalities in each of Q2 and Q1 (25-50% [0.664 : 0.984]) and (<25% [-0.787 : 0.984]), respectively. Furthermore, analysis identified three district municipalities (Metsweding, Pixley Ka Seme, and Dr Kenneth Kaunda) in Gauteng, Northern Cape, and North West provinces respectively as upper outliers ([0.019 : infinity]) for the female standardised TB death rates in 2005, similar to the female crude TB death rates in 2005. There were no district municipalities identified as lower outliers (see Figure

5.26). The distribution of standardised TB death rates among the district municipalities was similar to the findings of the 2005 female crude TB death rates.

Figure 5.26: *Standardised Tuberculosis Death Rates Box Map by District Municipality and Female, 2005*
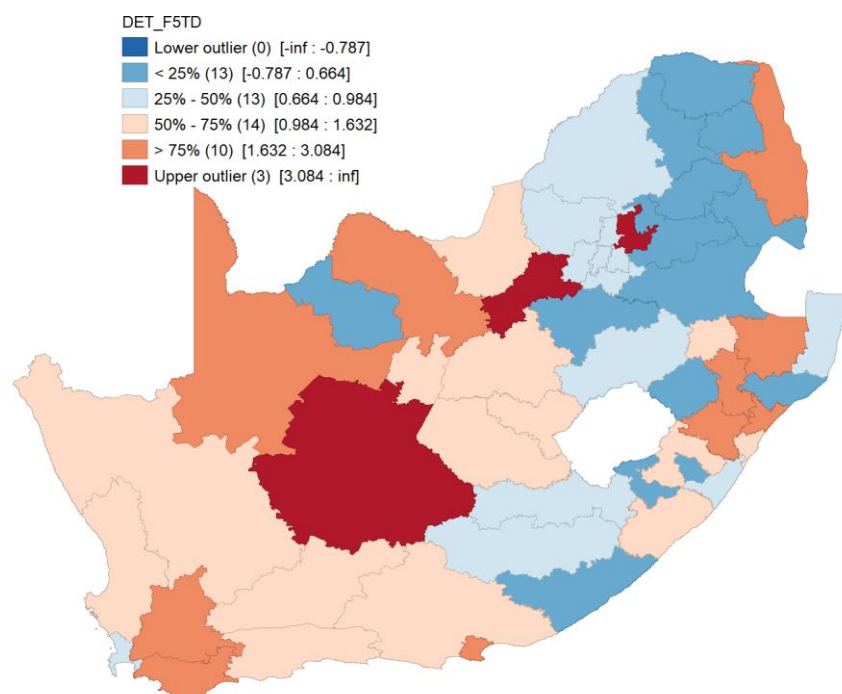
5.13.11 Standardised TB death rates box mapping for female for 2010

Based on the results of the 2010 female standardised TB death rates box map analysis, 13 district municipalities were identified in Q4 (>75% [1.563 : 2.835]) with another 13 in Q3 (50-75% [1.100 : 1.563]). A further 13 district municipalities each in Q2 and Q1 were identified (25-50% [0.715 : 1.563]) and (<25% [-0.557 : 0.715]), respectively. No upper or lower outliers were identified. This analysis yielded results similar to the female crude TB death rates of 2010 (see Figure 5.27).

Figure 5.27: *Standardised Tuberculosis Death Rates Box Map by District Municipality and Female, 2010*
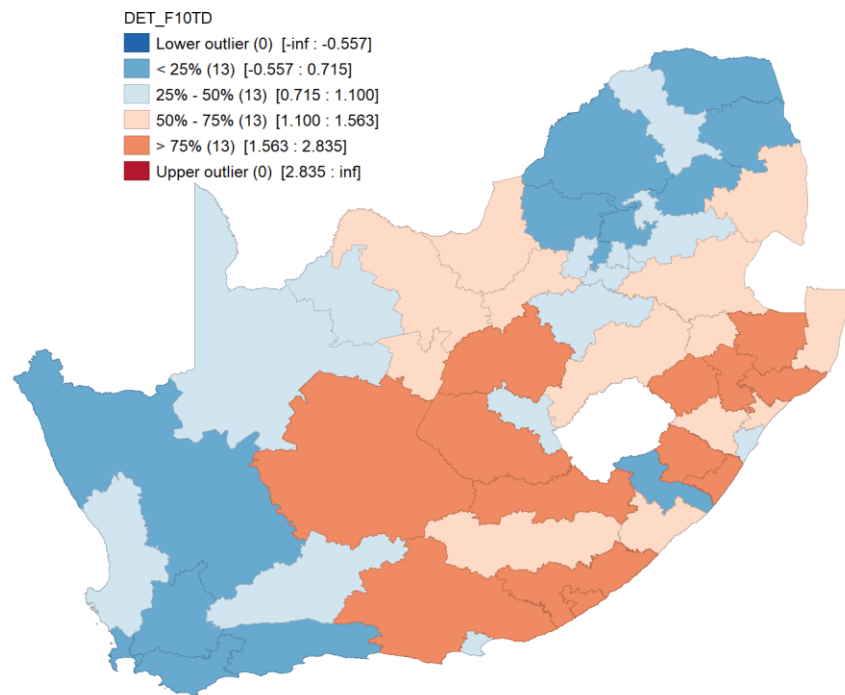
5.14 Local spatial clustering for TB notification rates

In this section, results for the Local Moran's I unadjusted TB notification rates will be presented. The results for the overall unadjusted TB notification rates for both 2005 and 2010 will be presented first, followed by those of the male covering 2005 and 2010 and then those for the female for the same period under study. The next results to be presented are those for the overall age sex standardised TB notification rates for 2005 and 2010; followed by the local spatial clustering of the age sex standardised TB notification rates for male for 2005 and 2010. Lastly, the results for the female age sex standardised TB notification rates for 2005 and 2010 will be presented.

5.14.1 Overall unadjusted TB notification rates for 2005

The results of the local Moran's I clustering for the overall unadjusted TB notification rates in 2005 revealed two high-high clusters of the overall unadjusted TB notification rates located in two district municipalities that neighboured each other (Siyanda and Frances Baard) in Northern Cape province. These two district municipalities are located on the western part of the country. Furthermore, results identified seven low-low clusters for the overall unadjusted TB notification rates that were located in seven district municipalities (Capricorn, Greater Sekhukhune, Gert Sibande, Ehlanzeni, Nkangala, Bohlabela, and Waterberg) on the northern part of the country. The results further revealed two low-high spatial outliers in Namakwa and

John Taolo Gaetsewe district municipalities in Northern Cape province and no high-low spatial outliers in 2005 (see Figure 5.28).

Figure 5.28: *Local Moran's I Clustering of Overall Unadjusted Tuberculosis Notification Rates by District Municipality, 2005*
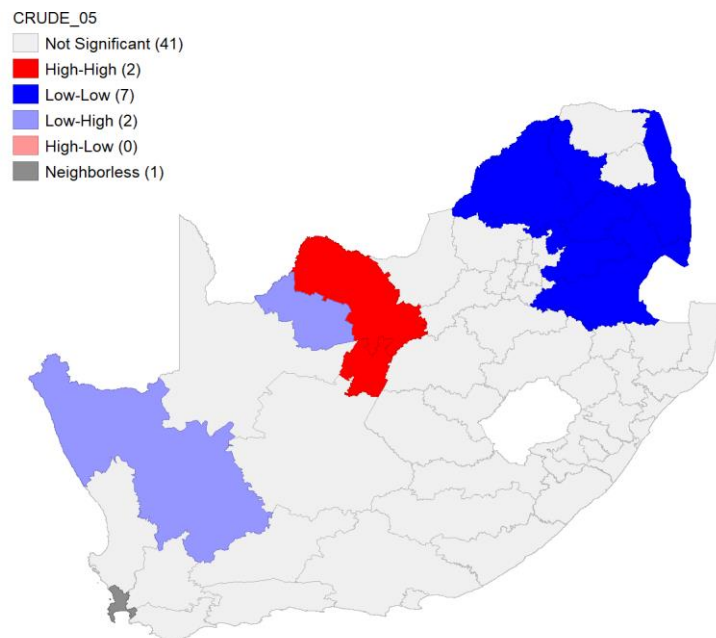
5.14.2 Overall unadjusted TB notification rates for 2010

The 2010 results of the local Moran's I clustering for the overall unadjusted TB notification rates revealed seven high-high clusters in seven district municipalities (uThungulu, Umzinyathi, iLembe, uMgungundlovu, Ugu, Sisonke, and eThekwini metropolitan) located on the eastern side of the country in KwaZulu-Natal province. These district municipalities neighboured each other. Furthermore, results identified nine low-low clusters of the overall unadjusted TB notification rates located in nine district municipalities (Mopani, Capricorn, Waterberg, Nkangala, Sedibeng, West Rand, Ekurhuleni metropolitan, City of Tshwane metropolitan, and City of Johannesburg metropolitan) in the northern part of South Africa. Results further revealed one low-high spatial outlier in Alfred Nzo district municipality in Eastern Cape province and one high-low spatial outlier in Ehlanzeni district municipality in Mpumalanga province (see Figure 5.29). Results showed that the high-high overall unadjusted TB notification rates clusters for 2005 and 2010 were located on different parts of the country (see Figures 5.28 and 5.29).

Figure 5.29: *Local Moran's I Clustering of Overall Unadjusted Tuberculosis Notification Rates by District Municipality, 2010*
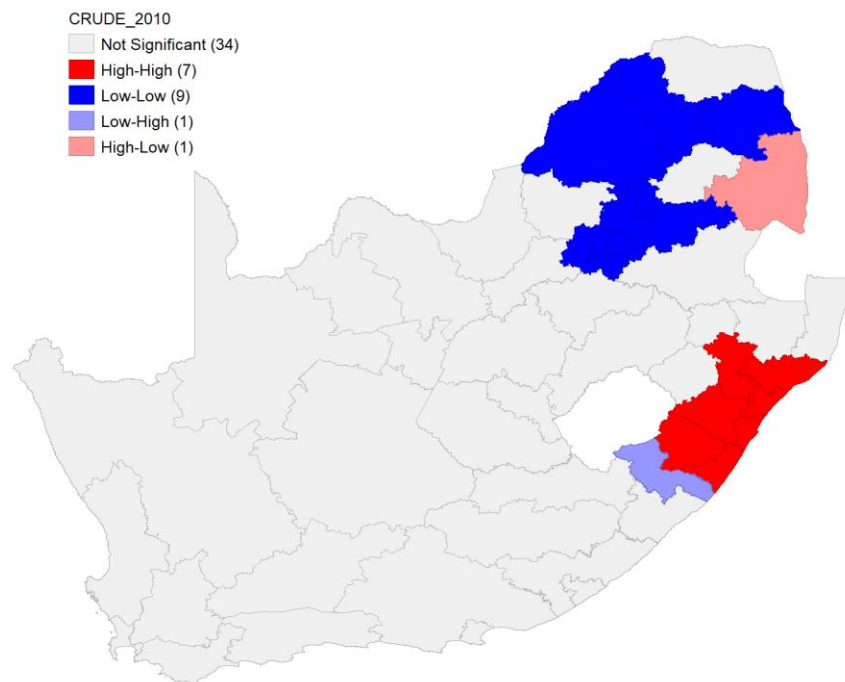
5.14.3 Unadjusted TB notification rates for male in 2005

The results of the local Moran's I clustering for the male unadjusted TB notification rates in 2005 revealed four high-high clusters located in four district municipalities (Frances Baard, Ruth S Mompati, Overberg, and West Rand). These high-high clusters for the male unadjusted TB notification rates were located in four provinces (Gauteng, Northern Cape, North West, and Western Cape). In addition, results identified eight low-low clusters for the male unadjusted TB notification rates, located in eight district municipalities (Capricorn, Greater Sekhukhune, Gert Sibande, Ehlanzeni, Nkangala, Bohlabela, Vhembe, and Waterberg) on the northern part of the country. Results further revealed two low-high spatial outliers in Namakwa and Ngaka Modiri Molema district municipalities in Northern Cape and North West provinces, respectively. There were no high-low spatial outliers for the male unadjusted TB notification rates in 2005 (see Figure 5.30).

Figure 5.30: *Local Moran's I Clustering of Unadjusted Tuberculosis Notification Rates by District Municipality and Male, 2005*
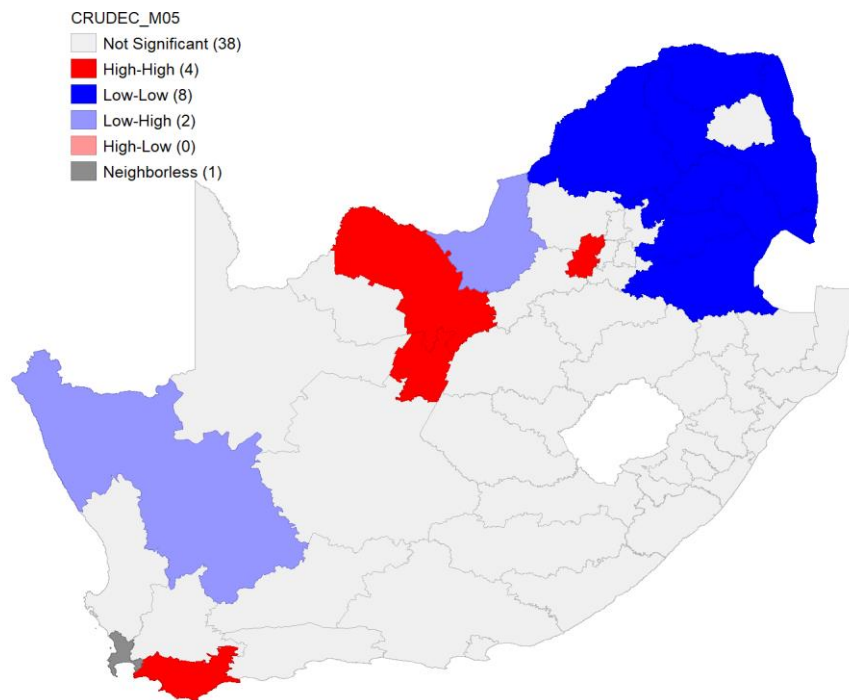
5.14.4 Unadjusted TB notification rates for male in 2010

The results of the local Moran's I clustering for the male unadjusted TB notification rates for 2010 revealed eight high-high clusters in eight district municipalities (Zululand, uThungulu, Umzinyathi, iLembe, uMgungundlovu, Ugu, Sisonke, and eThekwini metropolitan). These eight district municipalities were located in KwaZulu-Natal province on the eastern side of the country. These results identified 10 low-low clusters for the male unadjusted TB notification rates that were located in 10 district municipalities (Capricorn, Mopani, Waterberg, Sekhukhune, Nkangala, Sedibeng, West Rand, Ekurhuleni metropolitan, City of Tshwane metropolitan, and City of Johannesburg metropolitan) in the northern part of South Africa. Results further revealed one low-high spatial outlier for the male unadjusted TB notification rates in Alfred Nzo district municipality in Eastern Cape province and a high-low spatial outlier in Ehlanzeni district municipality in Mpumalanga province in 2010 (see Figure 5.28). These results were similar to those of the overall unadjusted TB notification rates of 2010 and they both showed that the high-high clusters for the unadjusted TB notification rates for 2005 and 2010 were located on different parts of the country, western and eastern respectively (see Figures 5.30 and 5.31).

Figure 5.31: *Local Moran's I clustering of unadjusted Tuberculosis notification rates by District Municipality and Male, 2010*
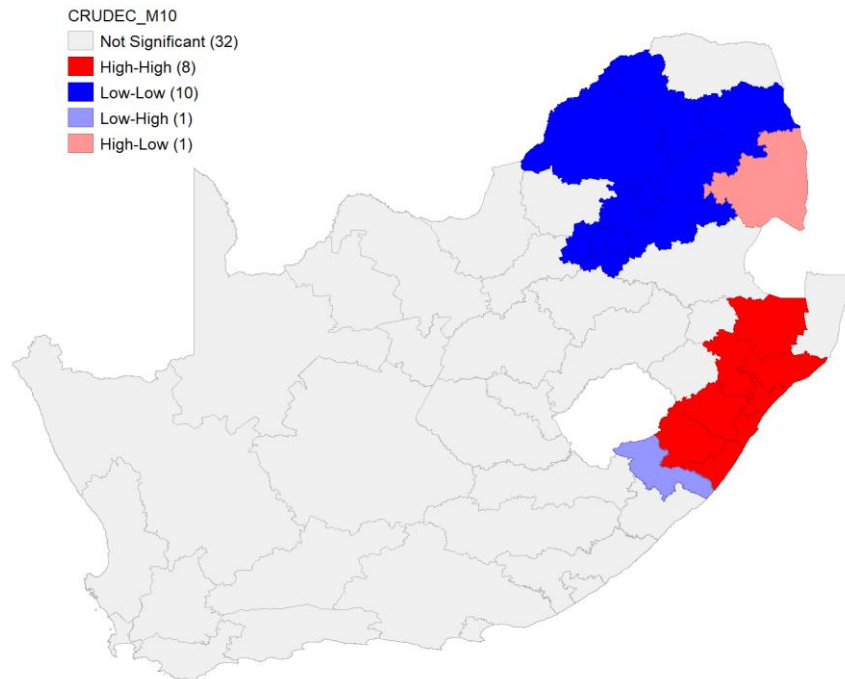
5.14.5 Unadjusted TB notification rates for female in 2005

Results of the local Moran's I clustering for the female unadjusted TB notification rates in 2005 revealed four high-high clusters located in four district municipalities (Frances Baard, Ngaka Modiri Molema, Ruth S Mompati, and Lejweleputswa). These high-high clusters for the female unadjusted TB notification rates were located in three provinces (Free State, Northern Cape, and North West) on the north western part of the country. Furthermore, results identified nine low-low clusters for the female unadjusted TB notification rates located in nine district municipalities (Capricorn, Greater Sekhukhune, Ehlanzeni, Nkangala, Metsweding, Bohlabela, Mopani, Vhembe, and Waterberg) on the northern part of the country. These district municipalities were located in three provinces (Gauteng, Limpopo, and Mpumalanga). Results further revealed three low-high spatial outliers for the female unadjusted TB notification rates in Namakwa, John Taolo Gaetsewe, and West Rand district municipalities in Northern Cape and Gauteng provinces. Results also revealed that, in 2005, there were no high-low spatial outliers for the female unadjusted TB notification rates (see Figure 5.32).

Figure 5.32: *Local Moran's I Clustering of Unadjusted Tuberculosis Notification Rates by District Municipality and Female, 2005*

5.14.6 Unadjusted TB notification rates for female in 2010

The results of the local Moran's I clustering for the female unadjusted TB notification rates for 2010 revealed nine high-high clusters in nine district municipalities (eThekwini metropolitan, uThungulu, Umzinyathi, iLembe, uMgungundlovu, Ugu, uMkhanyakude, Sisonke, and Zululand) located in one province (KwaZulu-Natal) on the eastern side of the country. Results further identified nine low-low clusters for the female unadjusted TB notification rates located in nine district municipalities (Capricorn, Mopani, Waterberg, Nkangala, Ekurhuleni metropolitan, Sedibeng, West Rand, City of Tshwane metropolitan, and City of Johannesburg metropolitan) in the northern part of South Africa; specifically, Limpopo, Mpumalanga, and Gauteng provinces. Results further revealed one low-high spatial outlier for the female unadjusted TB notification rates in Alfred Nzo which is located in Eastern Cape province on the eastern side of the country. There was one high-low spatial outlier for the unadjusted TB notification rates in Ehlanzeni district municipality in Mpumalanga province in 2010 (see Figure 5.32). These results were similar to those of the overall and the male unadjusted TB notification rates in that they all showed high-high clusters for the unadjusted TB notification rates for 2005 and 2010 located in different parts of the country—western and eastern respectively (see Figures 5.32 and 5.33).

Figure 5. 33: *Local Moran's I Clustering of Unadjusted Tuberculosis Notification Rates by District Municipality and Female, 2010*
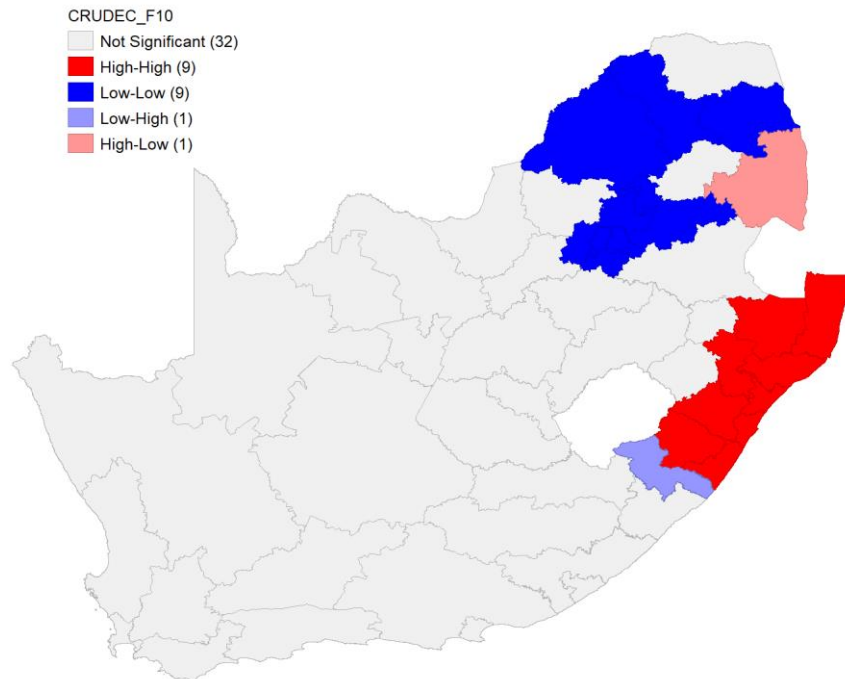
5.14.7 Overall age sex standardised TB notification rates in 2005

Two high-high clusters for the overall age sex standardised TB notification rates for 2005 were identified by the Local Moran's I analysis in Ruth S Mompati and Frances Baard district municipalities in North West and Northern Cape provinces, respectively. These are neighbouring district municipalities on the north western part of South Africa. As for the low-low clusters for the overall age sex standardised TB notification rates, seven were identified in Capricorn, Waterberg, Bohlabela, Greater Sekhukhune, Ehlanzeni, Nkangala, and Metsweding district municipalities. These district municipalities were located in three provinces (Gauteng, Limpopo, and Mpumalanga) on the northern part of the country. Furthermore, the Local Moran's I analysis identified three low-high clusters in John Taolo Gaetsewe, uThukela, and uThungulu district municipalities. Two of the low-high clusters were located on the eastern side, while the third was located on the western part of the country. Analysis did not reveal any high-low clusters for the overall age sex standardised TB notification rates of 2005 (see Figure 5.34).

Figure 5.34: *Local Moran's I Clustering of the Overall Age Sex Standardised Tuberculosis Notification Rates by District Municipality, 2005*
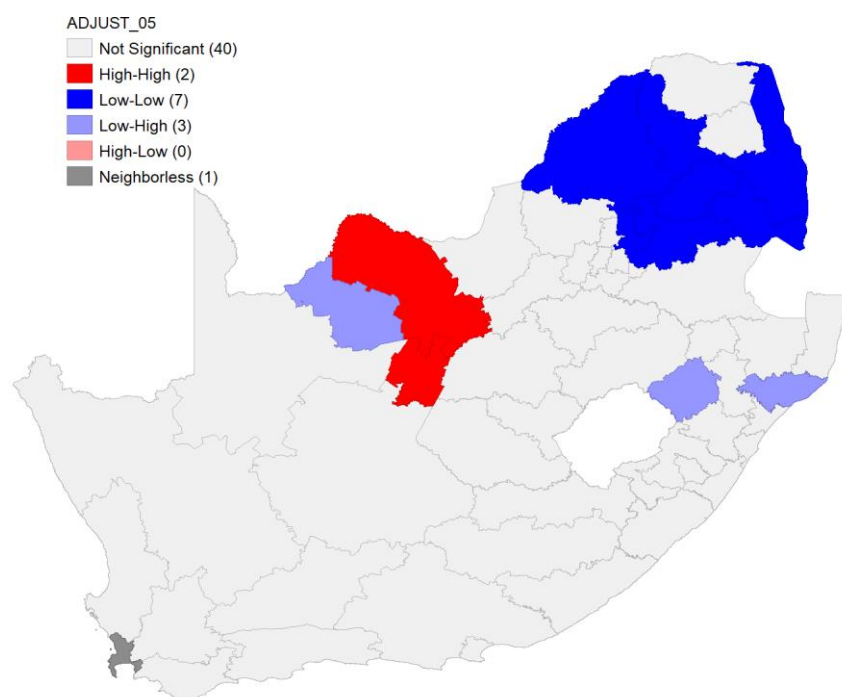
5.14.8 Overall age sex standardised TB notification rates in 2010

The Local Moran's I analysis for the overall age sex standardised TB notification rates of 2010 revealed seven high-high clusters in Amajuba, Zululand, Umzinyathi, iLembe, uThungulu, eThekwini metropolitan, and uMgungundlovu district municipalities all in KwaZulu-Natal province. These are neighbouring district municipalities on the eastern part of South Africa. Analysis further identified 10 low-low clusters for the overall age sex standardised TB notification rates in Capricorn, Mopani, Waterberg, Nkangala, West Rand, Sedibeng, Ekurhuleni metropolitan, City of Tshwane metropolitan, City of Johannesburg metropolitan, and Sedibeng district municipalities. These district municipalities were located in three provinces (Gauteng, Limpopo, and Mpumalanga) on the northern part of the country; the same location for the 2005 overall age sex standardised TB notification rates. Two low-high clusters were identified, one in Alfred Nzo district municipality in Eastern Cape province on the eastern side of the country and the other in Thabo Mofutsanyane district municipality in Free State province. A further two high-low clusters were identified, one in Mopani district municipality in Limpopo province and the other in Dr Kenneth Kaunda in North West province (see Figure 5.35).

Figure 5.35: *Local Moran's I Clustering of the Overall Age Sex Standardised Tuberculosis Notification Rates by District Municipality, 2010*
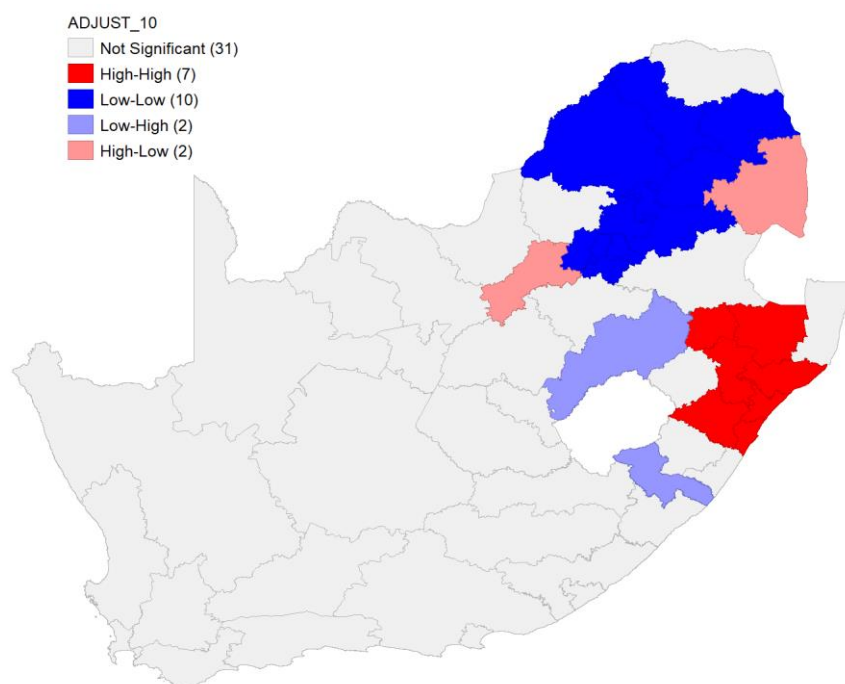
5.14.9 Age sex standardised TB notification rates for male in 2005

Similar to the overall age sex standardised TB notification rates of 2005, the Local Moran's I analysis identified two high-high clusters for the male age sex standardised TB notification rates. These two high-high clusters were in Ruth S Mompati and Frances Baard district municipalities in North West and Northern Cape provinces, respectively. Analysis further revealed six low-low clusters located in Ehlanzeni, Nkangala Waterberg, Bohlabela, Greater Sekhukhune, and Metsweding district municipalities. These six low-low clusters were located in three provinces (Gauteng, Limpopo, and Mpumalanga) on the northern part of the country. Furthermore, the Local Moran's I analysis identified two low-high clusters in uThukela and uTthungulu district municipalities which were located on the eastern side of the country in KwaZulu-Natal province. The Local Moran's I analysis for the male age sex standardised TB notification rates for 2005 did not reveal any high-low clusters (see Figure 5.36).

Figure 5.36: *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Male, 2005*
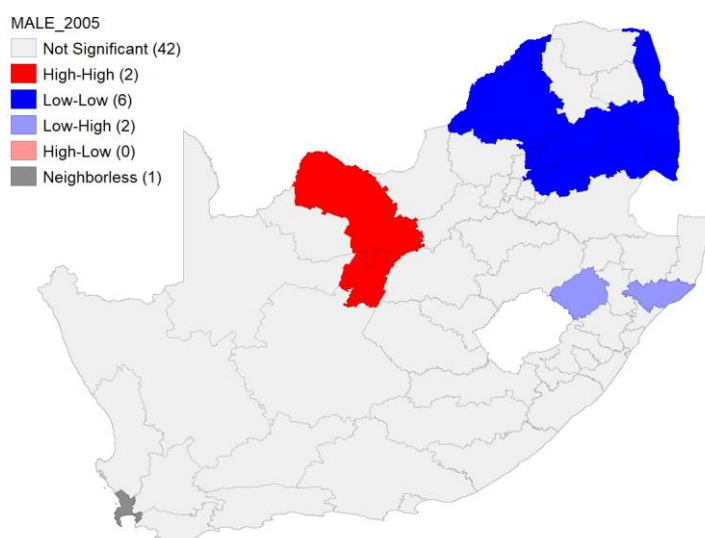
5.14.10 Age sex standardised TB notification rates for male in 2010

The results of the Local Moran's I analysis for the male age sex standardised TB notification rates for 2010 identified nine high-high clusters in KwaZulu-Natal province on the eastern side of the country. The high-high clusters were located in eThekwini metropolitan, Zululand, Umzinyathi, uThungulu, uThukela, uMgungundlovu, Ugu, iLembe, and Sisonke district municipalities. Similar to the 2010 results of the overall age sex standardised TB notification rates, eight low-low clusters for the male age sex standardised TB notification rates were identified in the same district municipalities (Capricorn, Waterberg, Nkangala, West Rand, Ekurhuleni metropolitan, City of Tshwane metropolitan, City of Johannesburg metropolitan, and Sedibeng). These district municipalities were located in three provinces (Gauteng, Limpopo, and Mpumalanga) on the northern part of the country. Analysis revealed one low-high cluster in Alfred Nzo district municipality in Eastern Cape province on the eastern side of the country. In 2010, the analysis identified two high-low clusters—one in Mopani district municipality in Limpopo province and the other in Dr Kenneth Kaunda in North West province. (see Figure 5.37).

Figure 5.37: *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Male, 2010*
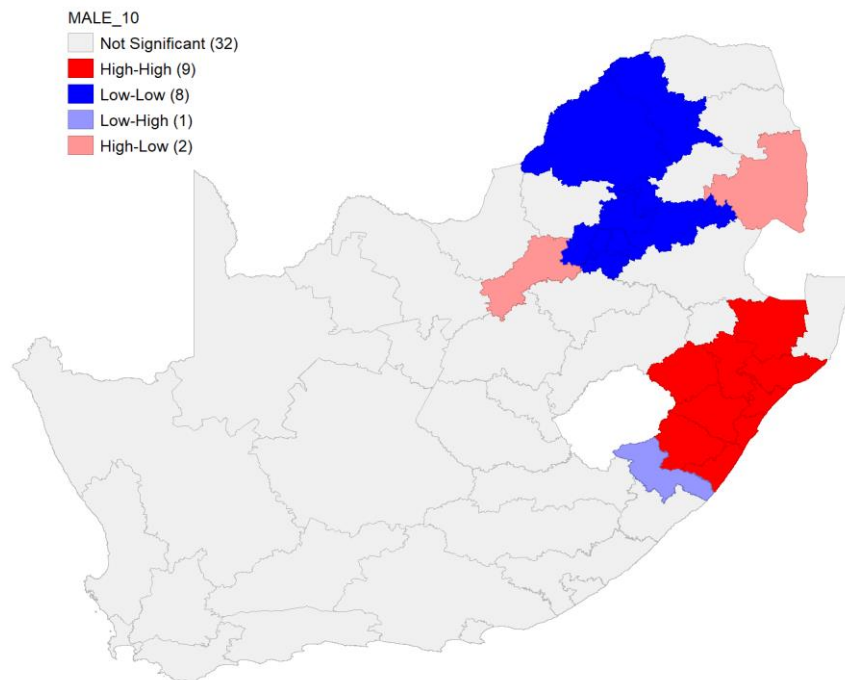
5.14.11 Age sex standardised TB notification rates for female in 2005

The two high-high clusters identified by the Local Moran's I analysis for the female age sex standardised TB notification rates of 2005 were the same for both the overall and the male age sex standardised TB notification rates for the same period. These two high-high clusters were on the north western part of the country in Ruth S Mompati and Frances Baard district municipalities in North West and Northern Cape provinces, respectively. Seven low-low clusters were identified, located in Capricorn, Ehlanzeni, Nkangala Waterberg, Bohlabela, Greater Sekhukhune, and Metsweding district municipalities. These seven low-low clusters were located in three provinces (Gauteng, Limpopo, and Mpumalanga) on the northern part of the country. Four low-high clusters were identified in Namakwa, John Taolo Gaetsewe, uThukela, and uThungulu district municipalities. These low-low clusters were located on the eastern side in KwaZulu-Natal province and on the western part of the country in Northern Cape province. The Local Moran's I analysis for the female age sex standardised TB notification rates for 2005 did not reveal any high-low clusters (see Figure 5.38).

Figure 5.38: *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Female, 2005*
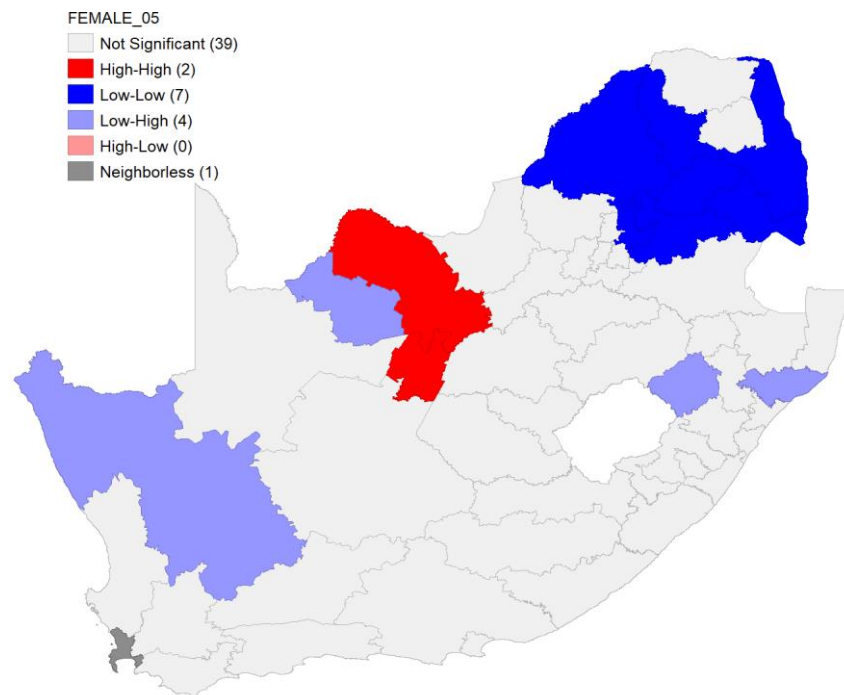
5.14.12 Age sex standardised TB notification rates for female in 2010

The Local Moran's I analysis for the female age sex standardised TB notification rates for 2010 identified nine high-high clusters in KwaZulu-Natal province on the eastern side of the country. These high-high clusters were located in eThekwini metropolitan, uMkhanyakude, Zululand, Umzinyathi, uThungulu, uMgungundlovu, Ugu, iLembe, and Sisonke district municipalities. Results showed nine low-low clusters for the female age sex standardised TB notification rates, located in Capricorn, Mopani, Waterberg, Nkangala, Ekurhuleni metropolitan, City of Johannesburg metropolitan, City of Tshwane metropolitan, West Rand, and Sedibeng district municipalities. These district municipalities were located in three provinces (Gauteng, Limpopo, and Mpumalanga) on the northern part of the country. Analysis revealed one low-high cluster in Alfred Nzo district municipality in Eastern Cape province. This is the same location for the low-high cluster which was identified for both the overall and male age sex standardised TB notification rates of 2010. Furthermore, the Local Moran's I identified two high-low clusters in Ehlanzeni and Dr Kenneth Kaunda district municipalities in Mpumalanga and North West provinces respectively (see Figure 5.39).

Figure 5.39: *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Female, 2010*
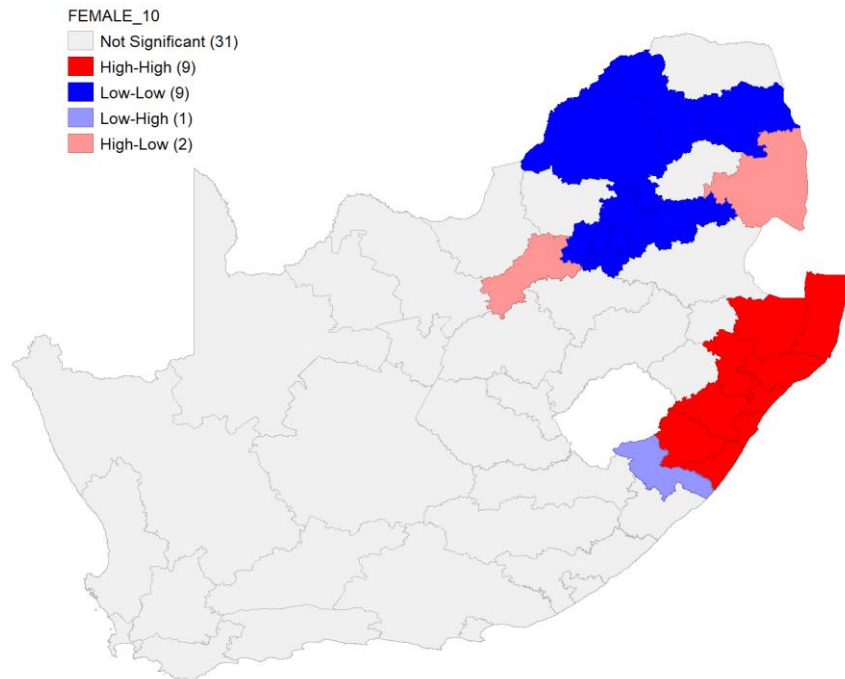
5.15 Local spatial clustering for TB death rates

This section presents results for the Local Moran's I for local spatial clustering of TB death rates. The results for the overall unadjusted TB death rates for 2005 and 2010 will be presented first, followed by the unadjusted TB death rates of male for 2005 and 2010, and then those for the female for the same period of study. The next set of results to be presented will be the age sex standardised TB death rates. These will begin with the overall age sex standardised TB death rates for 2005 and 2010, followed by the male age sex standardised TB death rates for 2005 and 2010 and, finally, the female age sex standardised TB death rates for the same period.

5.15.1 Overall unadjusted TB death rates for 2005

There were six high-high clusters for the overall unadjusted TB death rates of 2005 identified by the Local Moran's I analysis in Ruth S Mompati district municipality in North West province, eThekwini metropolitan and uMgungundlovu district municipalities in KwaZulu-Natal province, and Amathole, Nelson Mandela metropolitan, and Chris Hani district municipalities in Eastern Cape province. Five of the six high-high clusters were located on the eastern side of the country while one was located on the north western side. Analysis revealed a presence of 11 low-low clusters for the overall unadjusted TB death rates located in Cape Winelands district municipality in Western Cape province; Capricorn, Waterberg, Bohlabela,

Greater Sekhukhune, Vhembe, and Mopani district municipalities in Limpopo province; Nkangala district municipality in Mpumalanga province; and in Ekurhuleni metropolitan, City of Tshwane metropolitan, and Metsweding district municipalities in Gauteng province. The Local Moran's I analysis did not identify any low-high clusters or high-low clusters for the overall unadjusted TB death rates for 2005 (see Figure 5.40).

Figure 5.40: *Local Moran's I Clustering of the Overall Unadjusted Tuberculosis Death Rates by District Municipality, 2005*
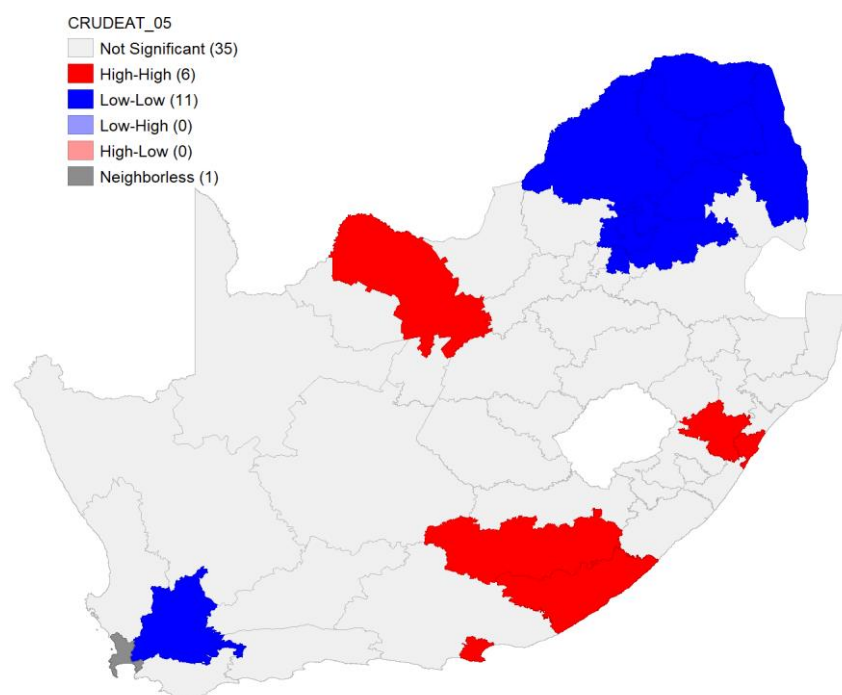
5.15.2 Overall unadjusted TB death rates for 2010

The results of the Local Moran's I analysis for the overall unadjusted TB death rates in 2010 identified four high-high clusters. The identified four high-high clusters were located on the eastern part of the country in Amajuba and uMgungundlovu district municipalities in KwaZulu-Natal province, and in Joe Gqabi and Chris Hani district municipalities in Eastern Cape province. Analysis further revealed a presence of 13 low-low clusters for the overall unadjusted TB death rates in 2010 located in City of Cape Town metropolitan, Overberg, Cape Winelands, and West Coast district municipalities in Western Cape province; Capricorn, Waterberg, Vhembe, and Mopani district municipalities in Limpopo province; and the City of Johannesburg metropolitan, Ekurhuleni metropolitan, City of Tshwane metropolitan, Sedibeng, and West Rand district municipalities in Gauteng province. Furthermore, the Local Moran's I analysis identified five low-high clusters in Frances Baard district municipality in Northern Cape province and in Mangaung metropolitan district municipality in Free State

province. The other low-high clusters were identified in eThekwini metropolitan and uThungulu district municipalities in KwaZulu-Natal province and Alfred Nzo in Eastern Cape province. In addition, there was one high-low cluster identified in Ehlanzeni district municipality in Mpumalanga province (see Figure 5.41).

Figure 5.41: *Local Moran's I Clustering of the Overall Unadjusted Tuberculosis Death Rates by District Municipality, 2010*
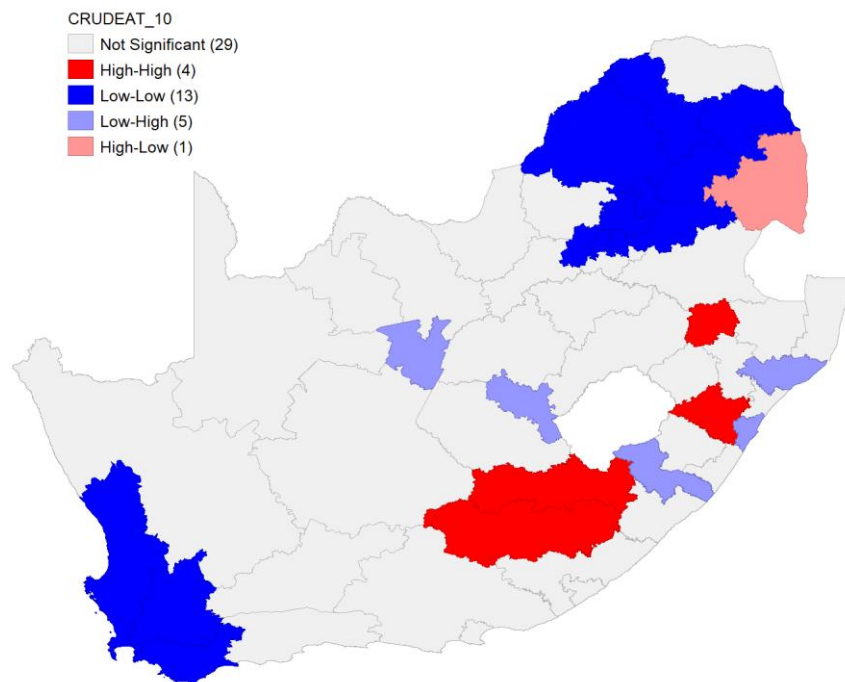
5.15.3 Unadjusted TB death rates for male in 2005

The Local Moran's analysis for clustering identified three high-high clusters for the unadjusted TB death rates for male in 2005. The identified high-high clusters were located in Frances Baard district municipality in Northern Cape province, Xhariep district municipality in Free State province, and Nelson Mandela metropolitan district municipality in Eastern Cape province. Two of these high-high clusters were more centrally located whereas the third was on the eastern side of the country. In addition to high-high clusters, results identified 11 low-low clusters in Cape Winelands district municipality in Western Cape province in the southern part of the country; and in Capicorn, Waterberg, Vhembe, Mopani, Bohlabela, Greater Sekhukhune district municipalities in Limpopo province; Nkangala district municipality in Mpumalanga province; as well as in the City of Tshwane metropolitan, Ekurhuleni metropolitan, and Metsweding district municipalities in Gauteng province. Two low-high clusters were revealed in Central Karoo and Chris Hani district municipalities in Western Cape

and Eastern Cape province, respectively. Analysis did not identify any high-low clusters (see Figure 5.42).
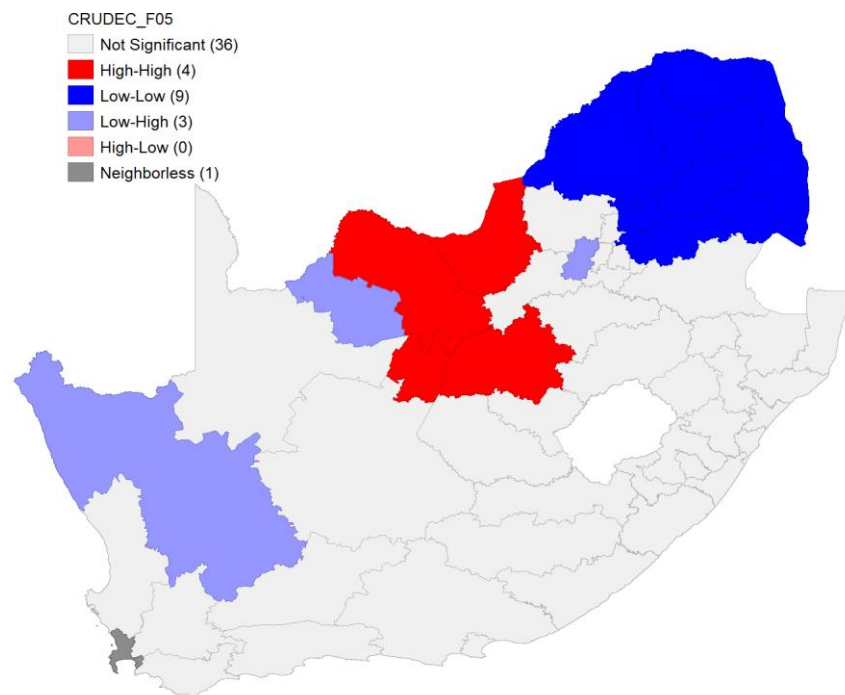
Figure 5.42: *Local Moran's I Clustering of the Unadjusted Tuberculosis Death Rates by District Municipality and Male, 2005*
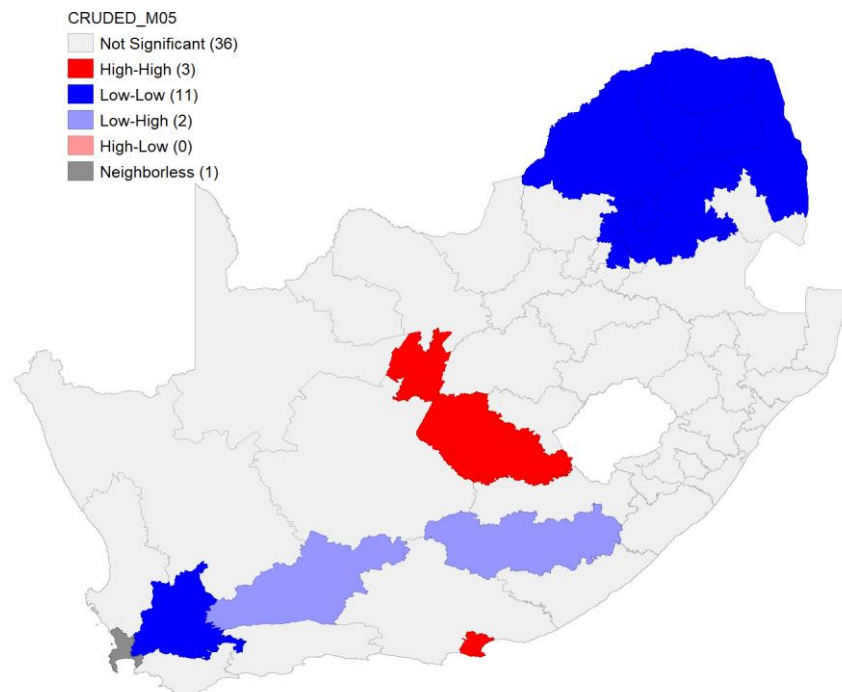
5.15.4 Unadjusted TB death rates for male in 2010

The location for the identified high-high clusters for the unadjusted TB death rates for male in 2010 was different from that of 2005. Seven high-high clusters were identified, one in Chris Hani district municipality in Eastern Cape province while the rest were in KwaZulu-Natal province within uMgungundlovu, Umzinyathi, Zululand, uMkhanyakude, uMgungundlovu, and uThungulu district municipalities. All of these high-high clusters were located on the eastern side of the country. The Local Moran's I analysis for clustering also identified 14 low-low clusters with four being in City of Cape Town metropolitan, Cape Winelands, West Coast, and Overberg district municipalities in Western Cape province in the southern part of the country. The other three were in Capricorn, Mopani, and Waterberg district municipalities in Limpopo province. One low-low cluster was located in Nkangala district municipality in Mpumalanga province. The remaining five low-low clusters were identified in the City of Tshwane metropolitan, Ekurhuleni metropolitan, City of Johannesburg metropolitan, Sedibeng, and West Rand district municipalities in Gauteng province. In addition, the Local Moran's I analysis identified four low-high clusters in Frances Baard in Northern Cape province, Mangaung metropolitan district municipality in Free State province, eThekwini

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metropolitan district municipality in KwaZulu-Natal province, and Alfred Nzo district municipality in Eastern Cape province. The Local Moran's I analysis for clustering further identified one high-low cluster in Ehlanzeni district municipality in Mpumalanga province (see Figure 5.43).

Figure 5.43: *Local Moran's I Clustering of the Unadjusted Tuberculosis Death Rates by District Municipality and Male, 2010*
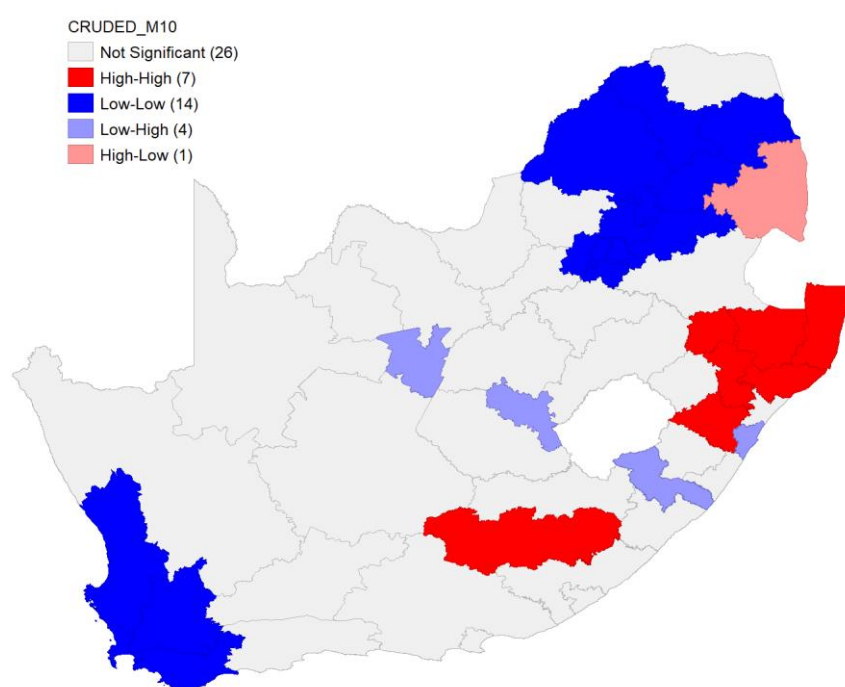
5.15.5 Unadjusted TB death rates for female in 2005
Similar to the results of the Local Moran's analysis for clustering for the unadjusted TB death rates for male in 2005, the results for the female unadjusted TB death rates also identified three high-high clusters. The identified high-high clusters were located in Frances Baard district municipality in Northern Cape province, Xhariep district municipality in Free State province, and Nelson Mandela metropolitan district municipality in Eastern Cape province. Again, two of these high-high clusters were more centrally located within the country whereas the third was on the eastern side. Furthermore, nine low-low clusters were identified; two were located in Cape Winelands and West Coast district municipalities in Western Cape province in the southern part of the country and seven were located in the northern part of the country in Capricorn, Waterberg, Vhembe, Mopani, Bohlabela district municipalities in Limpopo province; and the City of Tshwane metropolitan and Metsweding district municipalities in Gauteng province. Analysis revealed the same two low-high clusters as for the male unadjusted TB death rates in 2005 located in Central Karoo and Chris Hani district municipalities in

Western Cape and Eastern Cape provinces, respectively. There were no high-low clusters identified for the female unadjusted TB death rates in 2005 (see Figure 5.44).

Figure 5.44: *Local Moran's I Clustering of the Unadjusted Tuberculosis Death Rates by District Municipality and Female, 2005*
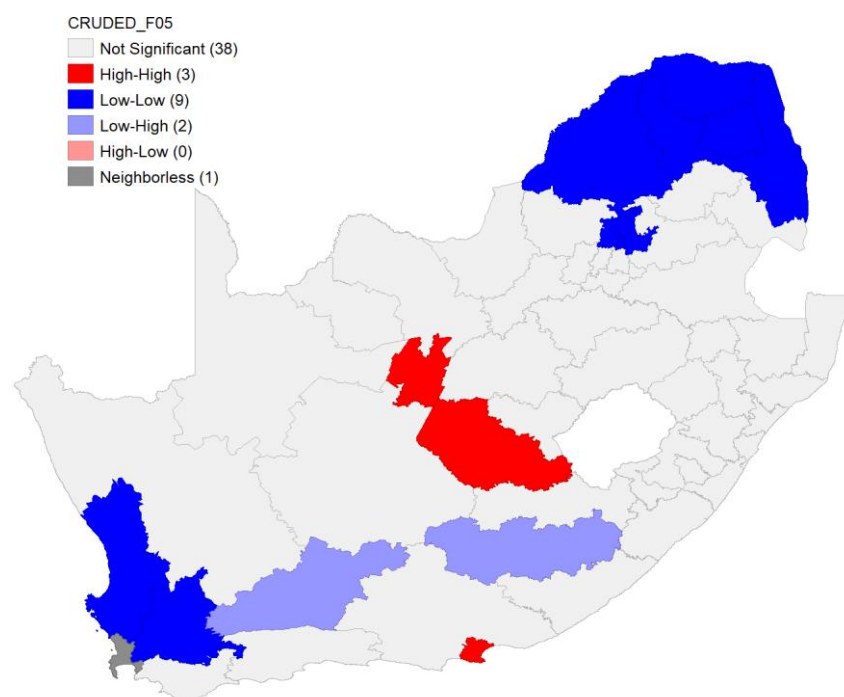
5.15.6 Unadjusted TB death rates for female for 2010

The results of the Local Moran's I analysis for the female unadjusted TB death rates in 2010 identified six high-high clusters; five were located on the eastern part of the country in Amajuba, uMkhanyakude, Zululand, uMgungundlovu, and Umzinyathi district municipalities in KwaZulu-Natal province; and one was centrally located in Lejweleputswa district municipality, Free State province. Analysis further revealed a presence of 13 low-low clusters for the overall unadjusted TB death rates in 2010. These low-low clusters were located in the City of Cape Town metropolitan, Cape Winelands, Overberg, and West Coast district municipalities in Western Cape province; Capricorn, Mopani, Sekhukhune, and Waterberg district municipalities in Limpopo province. One low-low cluster was located in Nkangala district municipality in Mpumalanga province. The remaining low-low clusters were located in the City of Johannesburg metropolitan, Ekurhuleni metropolitan, City of Tshwane metropolitan, Sedibeng, and West Rand district municipalities in Gauteng province. In addition, five low-high clusters were identified; one each in Frances Baard district municipality in Northern Cape province and Mangaung metropolitan district municipality in Free State province. The other two low-high clusters were identified in eThekwini metropolitan

municipality in KwaZulu-Natal province and Chris Hani and Alfred Nzo district municipalities in Eastern Cape province. In 2010, there was no high-low cluster that was identified for the female unadjusted TB death rates (see Figure 5.45).

Figure 5.45: *Local Moran's I Clustering of the Unadjusted Tuberculosis Death Rates by District Municipality and Female, 2010*
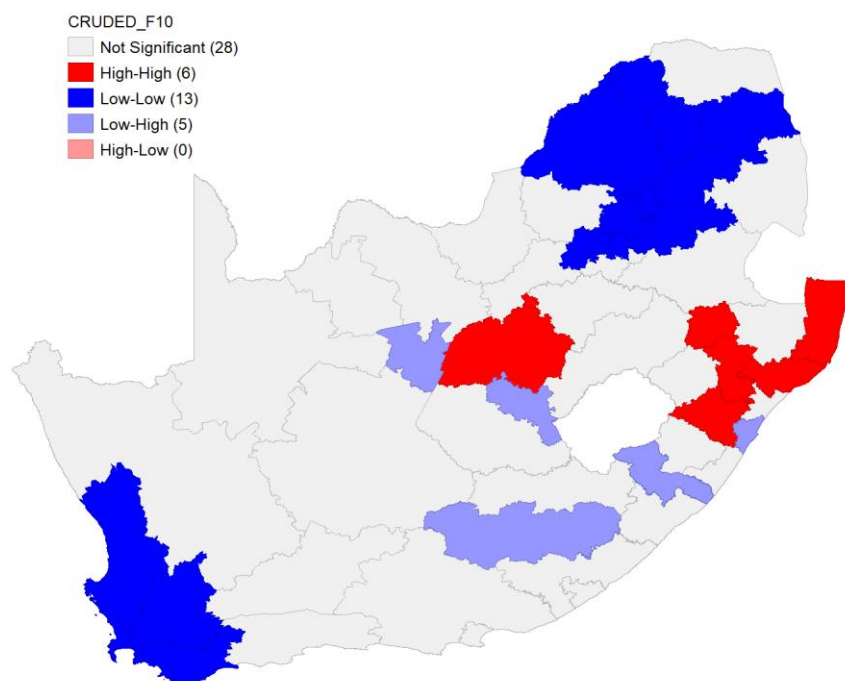
5.15.7 Overall age sex standardised TB death rates in 2005

In 2005, 11 high-high clusters were identified by the Local Moran's I analysis for clustering of the overall age sex standardised TB death rates. Three were located in Free State province in Lejweleputswa, Mangaung metropolitan, and Xhariep district municipalities. The rest were located in KwaZulu-Natal province in Amajuba, iLembe, uThungulu, uMgungundlovu, uThukela, Sisonke, eThekwini metropolitan, Umzinyathi, and Zululand district municipalities. Eight high-high clusters were located on the eastern side of the country and three in the central part. Analysis for clustering further revealed a presence of 10 low-low clusters for the overall age sex standardised TB death rates in 2005. Five of the identified 10 low-low clusters were located on the western side in Namakwa district municipality in Northern Cape province and Cape Winelands, West Coast, Eden, and Central Karoo district municipalities in Western Cape province. The other five low-low clusters were located on the northern part of the country in Capricorn and Waterberg district municipalities in Limpopo Province and Ekurhuleni metropolitan, City of Tshwane metropolitan, and Metsweding district municipalities in Gauteng province. Furthermore, the Local Moran's I analysis identified three low-high clusters

in Fezile Dabi district municipality in Free State province, uThungulu district municipality in KwaZulu-Natal province, and OR Tambo district municipality in Eastern Cape province. One high-low cluster was identified for the overall age sex standardised TB death rates for 2005 in Bohlabela district municipality in Limpopo province (see Figure 5.46).

Figure 5.46: *Local Moran's I Clustering of the Overall Age Sex Standardised Tuberculosis Death Rates by District Municipality, 2005*
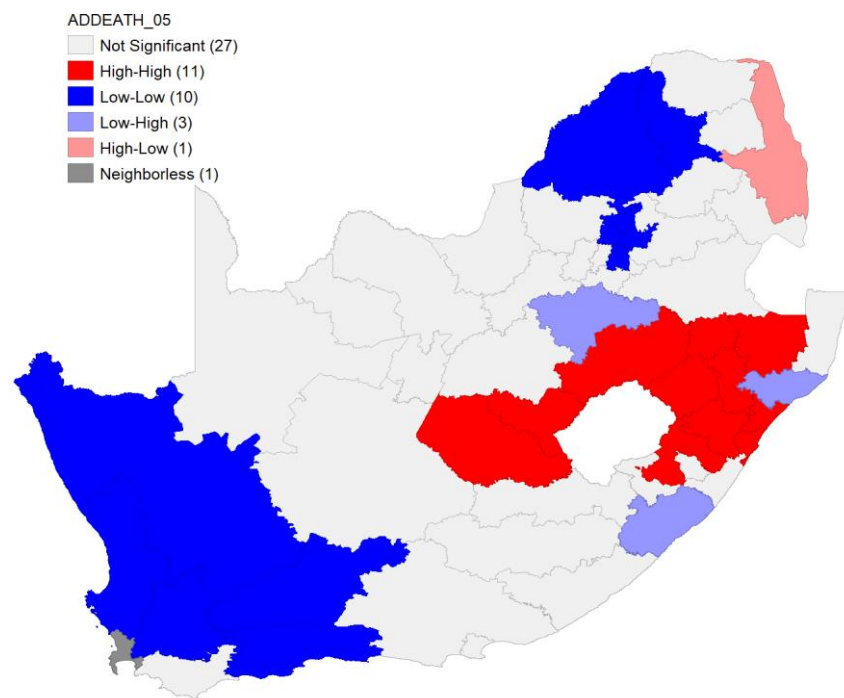
5.15.8 Overall age sex standardised TB death rates for 2010

The Local Moran's I analysis for clustering for the overall age sex standardised TB death rates revealed six high-high clusters in 2010 with one high-high cluster located in Thabo Mofutsanyane district municipality in Free State province and another located in Chris Hani district municipality in Eastern Cape Province. The rest were located in KwaZulu-Natal province in Amajuba, uMgungundlovu, uThukela, and Umzinyathi district municipalities. Ten low-low clusters for the overall age sex standardised TB death rates were identified in 2010. Some of them were located on the western side in the City of Cape Town metropolitan, Cape Winelands, West Coast, and Overberg district municipalities in Western Cape province; the other low-low clusters were located on the northern part of the country in Capricorn and Waterberg district municipalities in Limpopo province and Ekurhuleni metropolitan, City of Tshwane metropolitan, City of Johannesburg metropolitan, and West Rand district municipalities in Gauteng province. Furthermore, the Local Moran's I analysis identified one low-high cluster in uThungulu district municipality in KwaZulu-Natal province. However,

there were no high-low clusters that were identified for the overall age sex standardised age sex standardised TB death rates in 2010 (see Figure 5.47).

**Figure 5.47:** *Local Moran's I Clustering of the Overall Age Sex Standardised Tuberculosis Death Rates by District Municipality, 2010*
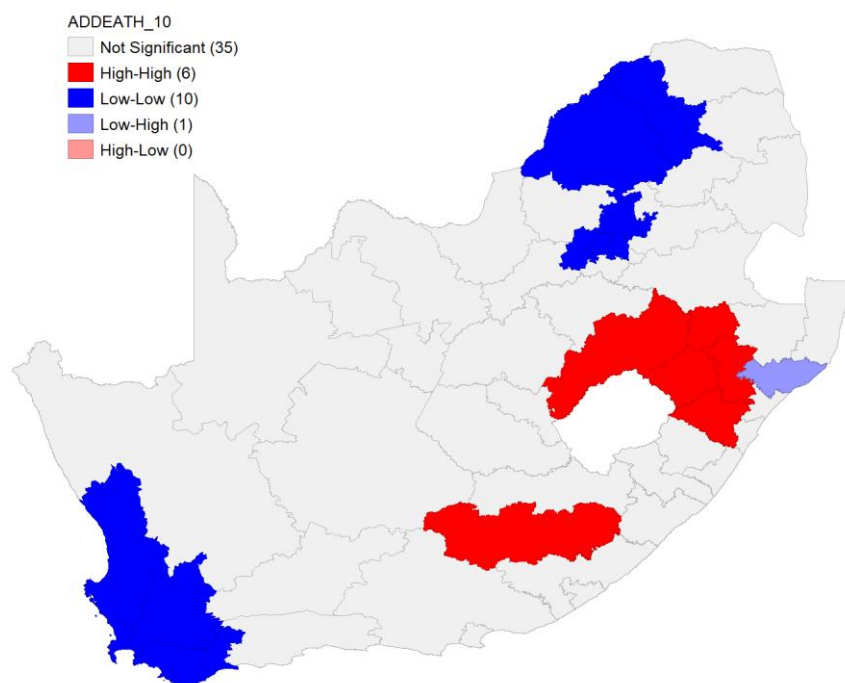
5.15.9 Age sex standardised TB death rates for male in 2005

Nine high-high clusters were identified by the Local Moran's I analysis for clustering of the male age sex standardised TB death rates in 2005. Two high-high clusters were located centrally in Free State province in Mangaung metropolitan and Thabo Mofutsanyane district municipalities. Meanwhile, the other seven high-high clusters were located in KwaZulu-Natal province in Amajuba, iLembe, uMgungundlovu, uThukela, Sisonke, Umzinyathi, and Zululand district municipalities, on the eastern side of the country. Furthermore, 12 low-low clusters for the male age sex standardised TB death rates were identified in 2005; two clusters in the south in Cape Winelands and Eden district municipalities in Western Cape province. The other 10 low-low clusters were located in Bohlabela, Capricorn, Greater Sekhukhune, Mopani, Vhembe, and Waterberg district municipalities in Limpopo province; Ekurhuleni metropolitan, City of Tshwane metropolitan, and Metsweding district municipalities in Gauteng province; and Nkangala district municipality in Mpumalanga province. Furthermore, the Local Moran's I analysis identified three low-high clusters; two in KwaZulu-Natal province located in eThekwini metropolitan and uThungulu district municipalities and one in OR Tambo district

municipality in Eastern Cape province. In 2005 there were no high-low clusters identified for the male age sex standardised TB death rates (see Figure 5.48).

**Figure 5.48:** *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Male 2005*
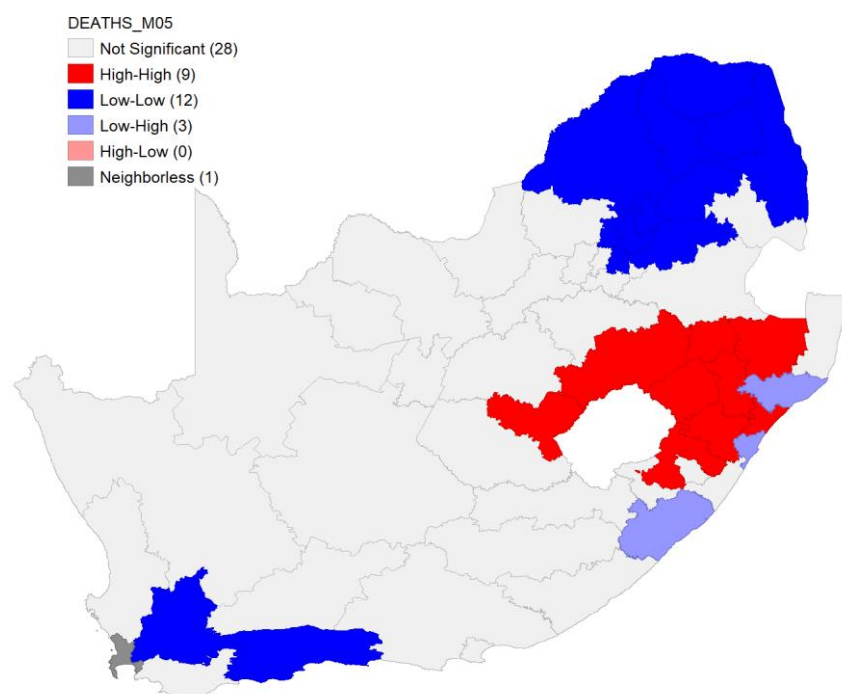
5.15.10 Age sex standardised TB death rates for male in 2010

Similar to the 2005 results, nine high-high clusters were identified by the Local Moran's I analysis for clustering of the male age sex standardised TB death rates in 2010, although not all of them were in the same district municipalities. Three high-high clusters were located in Eastern Cape province in Chris Hani, OR Tambo, and Joe Gqabi district municipalities. The other six high-high clusters were located in KwaZulu-Natal province in Amajuba, uMgungundlovu, uThukela, uThungulu, Umzinyathi, and Zululand district municipalities. All these high-high clusters were located on the eastern side of the country. In addition to the high-high clusters, 13 low-low clusters for the male age sex standardised TB death rates were identified in 2010. Four low-low clusters were located in the south of the country in the City of Cape Town metropolitan, Cape Winelands, Overberg, and Eden district municipalities in Western Cape province. The remaining eight low-low clusters were located in Bojanala district municipality in North West province; Nkangala district municipality in Mpumalanga province; Waterberg and Capricorn district municipalities in Limpopo province. The remainder of the low-low clusters were identified in Ekurhuleni metropolitan, City of Johannesburg metropolitan, City of Tshwane metropolitan, Sedibeng, and West Rand district municipalities

in Gauteng province. Furthermore, the Local Moran's I clustering analysis identified two low-high clusters in Northern Cape province located in Frances Baard district municipality and Mangaung metropolitan municipality in Free State province. In 2010 there were no high-low clusters identified for the male age sex standardised TB death rates (see Figure 5.49).

**Figure 5.49:** *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Male 2010*
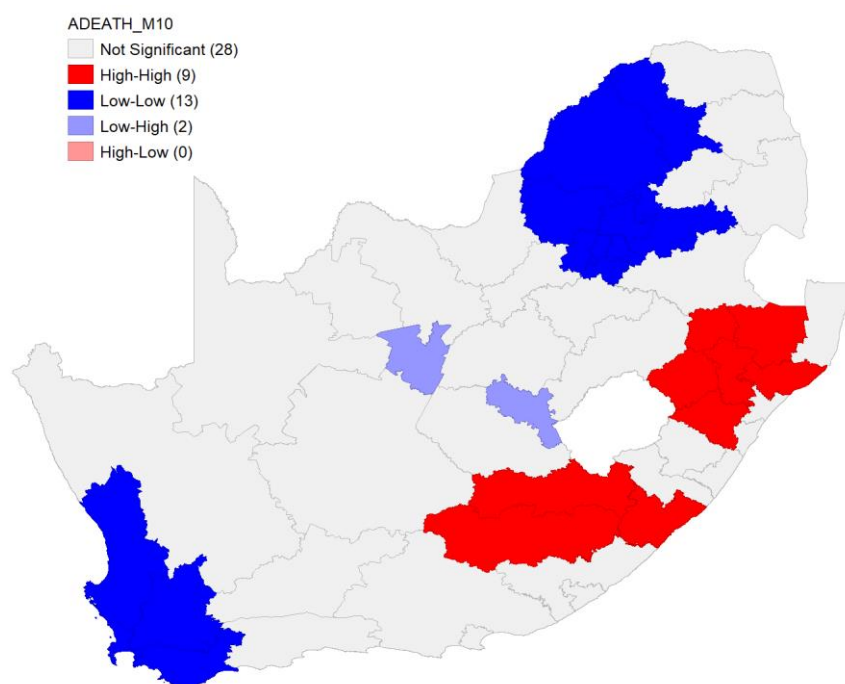
5.15.11 Age sex standardised TB death rates for female in 2005

The results of the Local Moran's I analysis for clustering identified 13 high-high clusters for the female age sex standardised TB death rates in 2005. Five clusters were located in the central part of the country, with one in Frances Baard district municipality in Northern Cape province. The other four were located in Free State province in Lejweleputswa, Mangaung metropolitan, Thabo Mofutsanyane, and Xhariep district municipalities. The remaining eight high-high clusters were located on the eastern side of the country in KwaZulu-Natal province in Amajuba, iLembe, uMgungundlovu, uThukela, Sisonke, eThekwini metropolitan, Umzinyathi, and Zululand district municipalities. The Moran's I analysis for clustering further identified a presence of 10 low-low clusters for the female age sex standardised TB death rates in 2005. Five low-low clusters were located in Cape Winelands, West Coast, Eden, Central Karoo, and Overberg district municipalities in Western Cape Province. The other five were located on the northern part of the country in Capricorn and Waterberg district municipalities in Limpopo province; as well as in Ekurhuleni metropolitan, City of Johannesburg, City of Tshwane

metropolitan, and Metsweding district municipalities in Gauteng province. In addition, the Local Moran's I analysis identified a presence of two low-high clusters, one in Fezile Dabi district municipality in Free State province and the other in uThungulu district municipality in KwaZulu-Natal province. One high-low cluster was identified for the female age sex standardised TB death rates in Bohlabela district municipality in Limpopo province in 2005 (see Figure 5.50).

Figure 5.50: *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Female 2005*
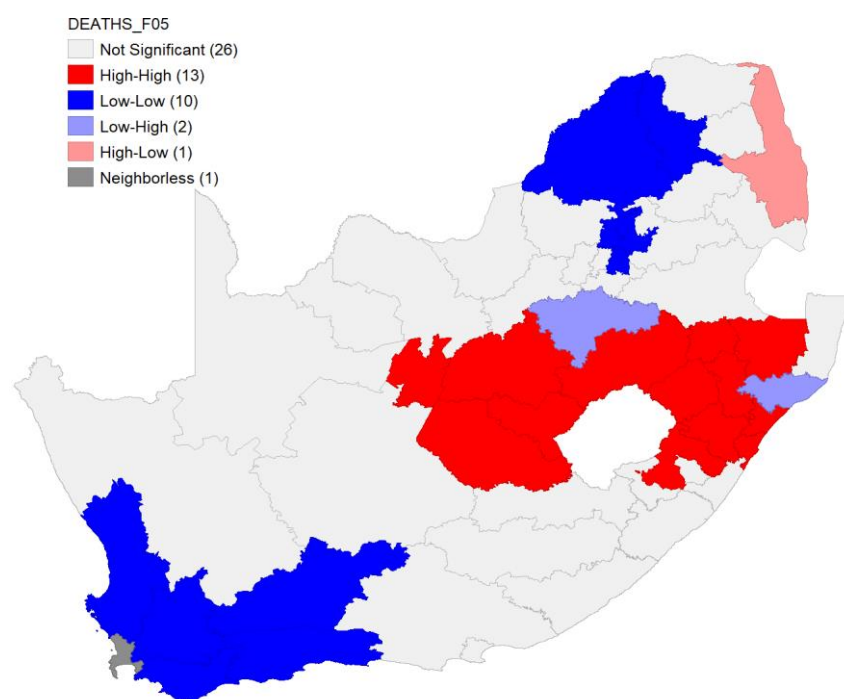
5.15.12 Age sex standardised TB death rates for female in 2010

In 2010, the results of the Local Moran's I analysis for clustering for the female age sex standardised TB death rates in 2010 identified five high-high clusters located on the eastern part of the country in Amajuba and uMzinyathi district municipalities in KwaZulu-Natal province; and Chris Hani, Joe Gqabi, and OR Tambo district municipalities in Eastern Cape province. Furthermore, the Local Moran's I revealed a presence of 10 low-low clusters of which some were located in the City of Cape Town metropolitan, Cape Winelands, Overberg, and West Coast district municipalities in Western Cape province; and others in Capricorn and Waterberg district municipalities in Limpopo province. The remaining low-low clusters were located in Gauteng province in the City of Johannesburg metropolitan, Ekurhuleni metropolitan, City of Tshwane metropolitan, and West Rand district municipalities. The results further revealed a presence of three low-high clusters with one each in Frances Baard district

municipality in Northern Cape province and the other in Mangaung metropolitan municipality in Free State province; whereas the other low-high cluster was identified in KwaZulu-Natal province in uThungulu district municipality. In 2010, there were no high-low clusters identified for the female age sex standardised TB death rates (see Figure 5.51).

Figure 5.51: *Local Moran's I Clustering of the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Female 2010*
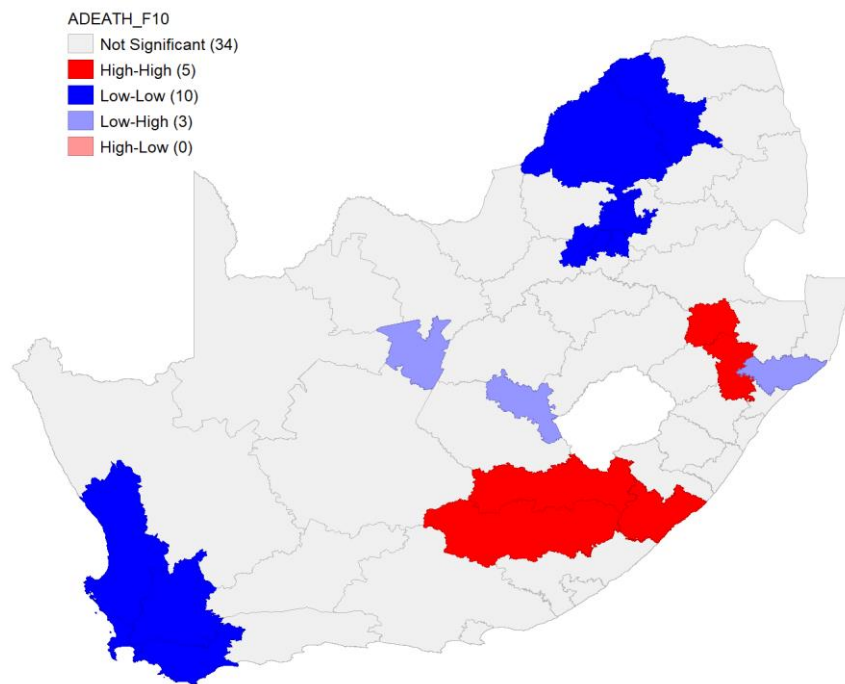

5.16 Intensity of TB notification rates (hot spots)

In this section, results of the Local G (hot spots) analysis will be presented. Like the sections prior, the results for the hot spots for the overall unadjusted TB notification rates for 2005 and 2010 will be presented first, followed by the unadjusted TB notification rates for the male for 2005 and 2010 and then those for the female for 2005 and 2010. Next, the hot spots for the age sex standardised TB notification rates will be presented, beginning with hot spots for the overall age sex standardised TB notification rates for the period 2005 and 2010. This will be followed by hot spots for the male age sex standardised TB notification rates for 2005 and 2010 and lastly the results of the hot spots for the female age sex standardised TB notification rates for the same period.

5.16.1 Overall unadjusted TB notification rates for 2005

Results of the Local G (hot spots) analysis for the overall unadjusted TB notification rates in 2005 revealed hot spots in four district municipalities (John Taolo Gaetsewe, Siyanda, Frances

Baard, and Namakwa) all located in Northern Cape province. The results revealed that cold spots were located in six district municipalities (Capricorn, Waterberg, Bohlabela, Ehlanzeni, Nkangala, and Greater Sekhukhune), in two provinces (Limpopo and Mpumalanga), located in the northern part of South Africa. These results further indicate that high TB risk areas in South Africa in 2005 were in the western part of the country and the low risk areas were in the northern part (see Figure 5.52).

Figure 5.52: *Local G Hot and Cold Spots for the Overall Unadjusted Tuberculosis Notification Rates by District Municipality, 2005*
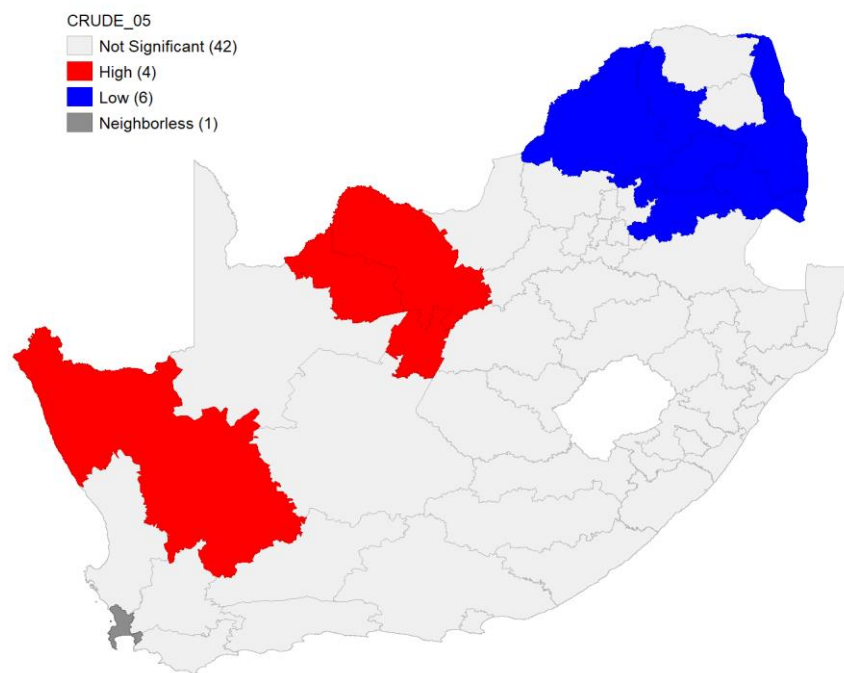
5.16.2 Overall unadjusted TB notification rates for 2010

In 2010, the results of the Local G (hot spots) analysis for the overall unadjusted TB notification rates revealed hot spots in eight district municipalities (Alfred Nzo, Zululand, Ugu, eThekwini, ilembe, uMgungundlovu, Umzinyathi, and uThungulu) located in two provinces (one in Eastern Cape and seven in KwaZulu Natal) on the eastern side of the country. Results revealed cold spots for the overall unadjusted TB notification rates in 2010 in 10 district municipalities (Capricorn, Waterberg, Mopani, West Rand, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Sedibeng, Ehlanzeni, and Nkangala) located in three provinces (Limpopo, Gauteng, and Mpumalanga) in the northern part of the country. In contrast to hot spots being located in different parts of the country in 2005 and 2010, cold spots were mainly located in the northern parts of the country in 2005 and 2010 (see Figure 5.53).

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Figure 5.53: *Local G Hot and Cold Spots for the Overall Unadjusted Tuberculosis Notification Rates by District Municipality, 2010*
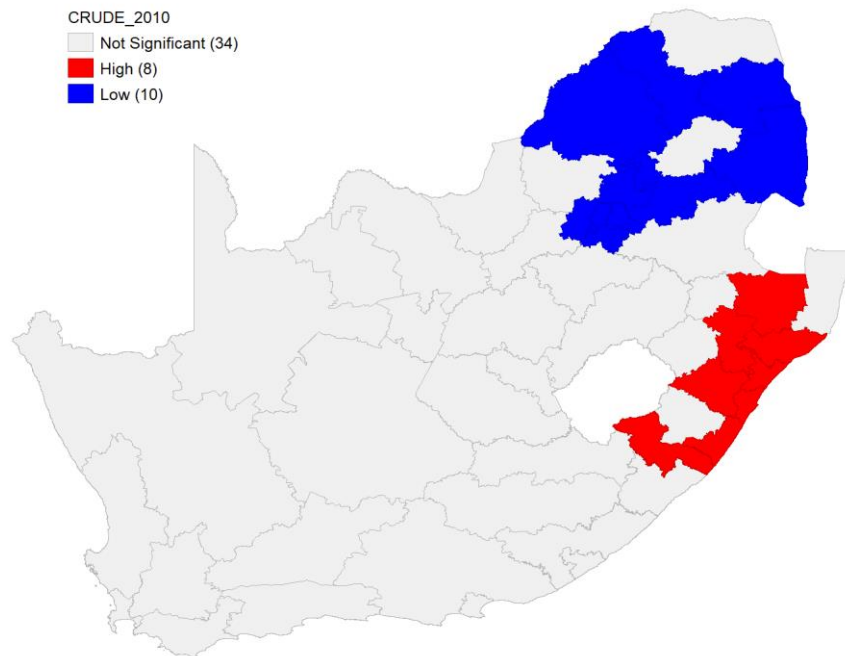
5.16.3 Unadjusted TB notification rates for male in 2005

Results of the Local G (hot spots) analysis for the male unadjusted TB notification rates in 2005 were similar to those of the overall unadjusted TB notification rates and they both showed hot spots in four district municipalities (John Taolo Gaetsewe, Siyanda, Frances Baard, and Namakwa) in Northern Cape province. Results further revealed that cold spots were in eight district municipalities (Waterberg, Vhembe, Mopani, Bohlabela, Ehlanzeni, Nkangala, Gert Sibande, and Greater Sekhukhune). Six of these district municipalities were the same ones where cold spots were identified for the overall unadjusted TB notification rates in 2005 (see Figure 5.54).

Figure 5.54: *Local G Hot and Cold Spots for the Unadjusted Tuberculosis Notification Rates by District Municipality and Male, 2005*
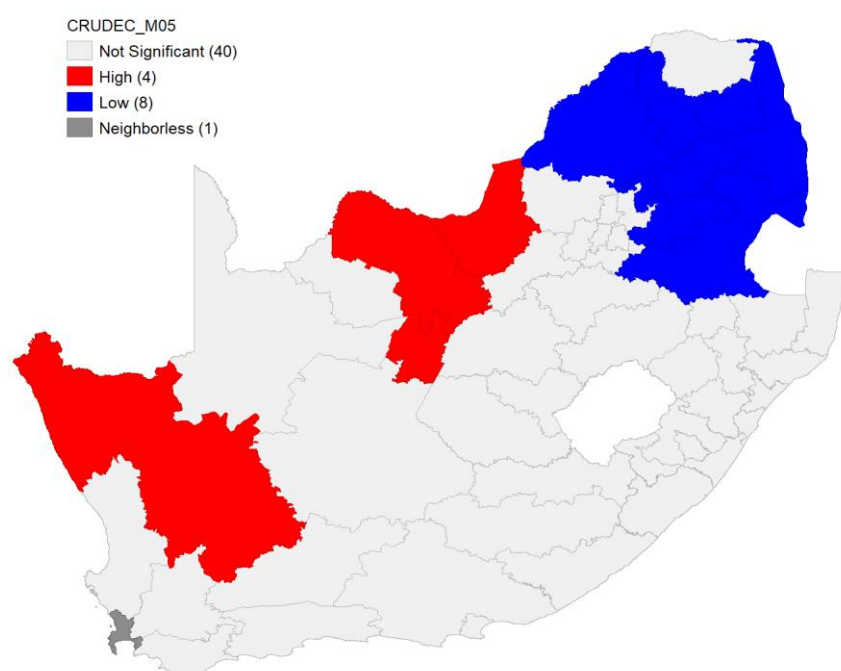
5.16.4 Unadjusted TB notification rates for male in 2010

Results of the 2010 Local G (hot spots) analysis for the male unadjusted TB notification rates revealed hot spots in eight district municipalities (Alfred Nzo, Zululand, Ugu, eThekwini, ilembe, uMgungundlovu, Umzinyathi, and uThungulu) located in two provinces (one in Eastern Cape and seven in KwaZulu Natal) on the eastern side of the country. These were the same district municipalities where hot spots were identified in the overall unadjusted TB notification rates for 2010. Results further indicated that there were cold spots for male unadjusted TB notification rates in 10 district municipalities (Capricorn, Waterberg, Mopani, West Rand, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Sedibeng Ehlanzeni, and Nkangala) in 2010 located in three provinces (Gauteng, Limpopo ,and Mpumalanga) in the northern part of the country. These results are similar to those of the overall unadjusted TB notification rates for 2010. Similar to the trend in the overall unadjusted TB rates, hot spots were located in different parts of the country, in western and eastern in 2005 and 2010 respectively, while cold spots were located in the same parts (northern) of the country for both 2005 and 2010 (see Figure 5.55).
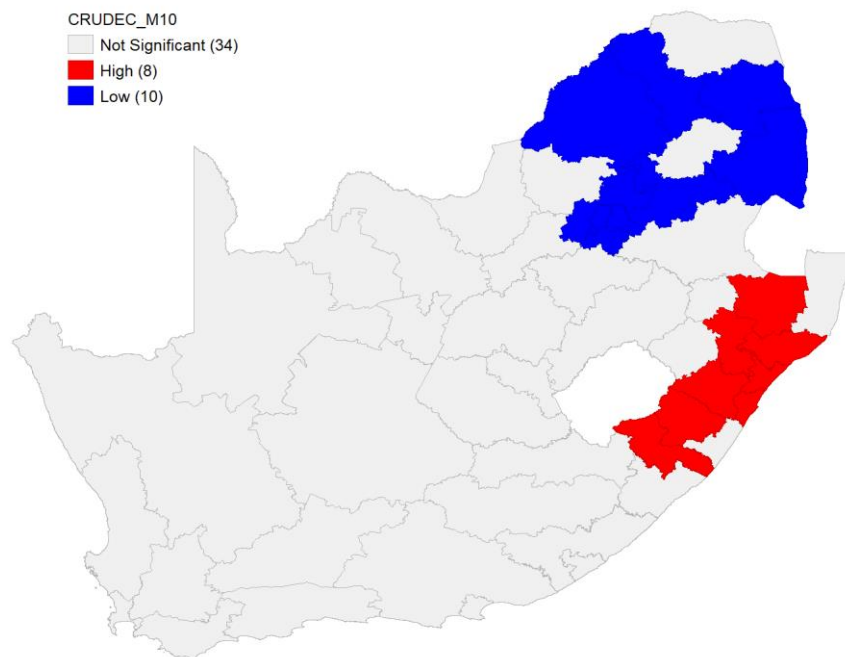
5.16.5 Unadjusted TB notification rates for female in 2005

Similar to the results of the Local Moran's I (hot spots) analysis for 2005, for both the overall and male unadjusted TB rates, four similar hot spots were identified for the female in 2005 and they were also located in the same district municipalities (John Taolo Gaetsewe, Siyanda, Frances Baard, and Namakwa) in Northern Cape province. However, there were two more district municipalities (Lejweleputswa and Ngaka Modiri Molema) with hot spots for the female unadjusted TB rates that were located in two different provinces (Free State and North West) on the western side of the country. Results further revealed that in 2005 there were cold spots for the female unadjusted TB notification rates located in eight district municipalities (Waterberg, Vhembe, Mopani, Bohlabela, Ehlanzeni, Nkangala, Gert Sibande, and Greater Sekhukhune). These were in two provinces (Limpopo and Mpumalanga) located in the northern part of the country. These were the same district municipalities with cold spots for the male in 2005. Therefore in 2005, high TB risk areas for female were also in the western part of the country while low risk areas were located in the northern part (see Figure 5.56).

Figure 5.56: *Local G Hot and Cold Spots for the Unadjusted Tuberculosis Notification Rates by District Municipality and Female, 2005*
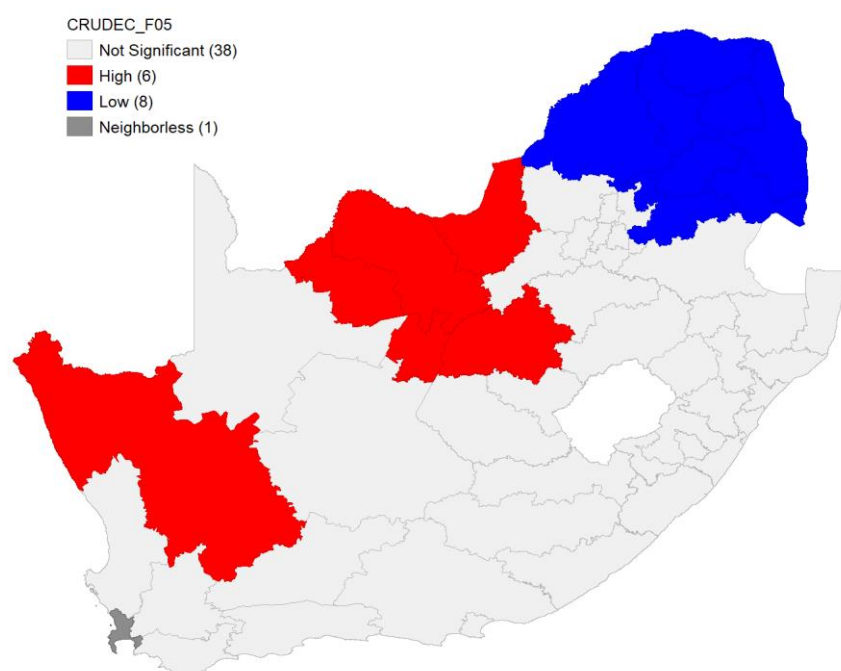
5.16.6 Unadjusted TB notification rates for female in 2010

The Local G (hot spots) results for 2010 for the female unadjusted TB notification rates were more or less similar to those for the overall and the male unadjusted 2010 TB notification rates. Results revealed hot spots in 10 district municipalities (Alfred Nzo, Zululand, Ugu, Sisonke, eThekwini, ilembe, uMgungundlovu, Umzinyathi, uMkhanyakude, and uThungulu)—one more hot spot compared to those for the overall and the male unadjusted TB notification rates in 2010. Similarly, hot spots were located in two provinces (one in Eastern Cape and nine in KwaZulu-Natal) on the eastern side of the country. Furthermore, results revealed 10 cold spots for the female unadjusted TB notification rates in the district municipalities of Capricorn, Waterberg, Mopani, West Rand, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Sedibeng, Ehlanzeni, and Nkangala in 2010. These were located in the provinces of Gauteng, Limpopo, and Mpumalanga in the northern part of the country. These results showed a similar trend to those of the overall and male unadjusted TB notification rates for 2010. Similar to the trend for the results of the overall and male unadjusted TB rates, hot spots were located in different parts of the country, in western and eastern in 2005 and 2010 respectively, while cold spots were located in the same parts (northern) of the country for both 2005 and 2010 (see Figure 5.57). The next section will present results for the Local G (hot spots) for the age sex standardised TB notification rates.

Figure 5.57: *Local G Hot and Cold Spots for the Unadjusted Tuberculosis Notification Rates by District Municipality and Female, 2010*
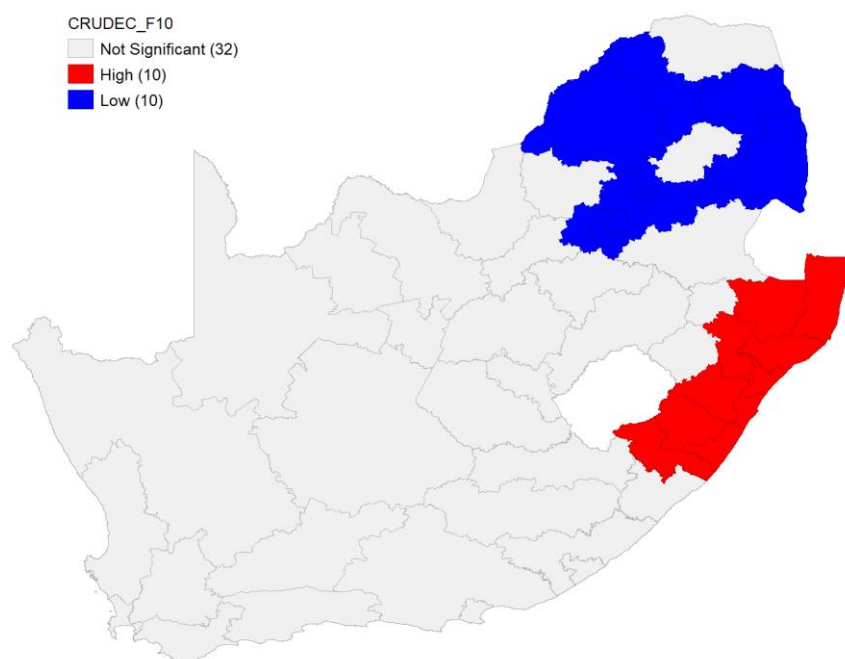
5.16.7 Overall age sex standardised TB notification rates for 2005

Results of the Local G (hot spots) analysis for the overall age sex standardised TB notification rates for 2005 revealed four hot spots—two on the western part and two on the eastern part of South Africa. The western hot spots were located in Ruth S Mompati and Frances Baard district municipalities in North West and Northern Cape provinces, respectively. The other two hot spots were located in uThungulu and uThukela in KwaZulu-Natal province on the eastern side of the country. Results further revealed cold spots for the overall age sex standardised TB notification rates in seven district municipalities (Waterberg, Capricorn, Greater Sekhukhune, Bohlabela, Ehlanzeni, Nkangala, and Metsweding) located in the northern part of the country. Compared with the results of the overall unadjusted TB notification rates for 2005, the results for the overall age sex standardised TB notification rates revealed hot spots in KwaZulu-Natal Province that were not identified with the unadjusted rates (see Figure 5.58).

Figure 5.58: *Local G Hot and Cold Spots for the Overall Age Sex Standardised Tuberculosis Notification Rates by District Municipality, 2005*

ADJUST_05
☐ Not Significant (41)
■ High (4)
■ Low (7)
■ Neighborless (1)
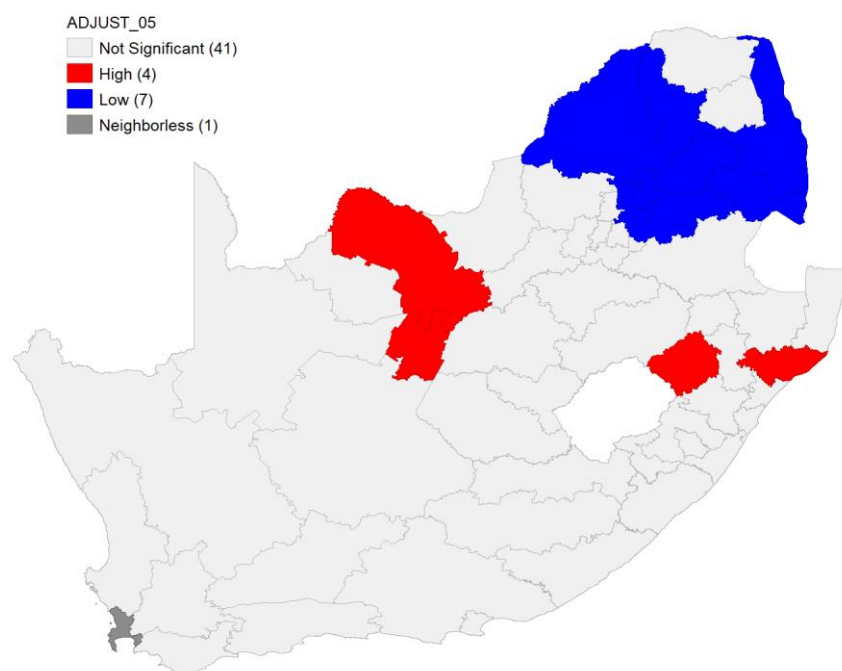
5.16.8 Overall age sex standardised TB notification rates in 2010

The 2010 results of the Local G (hot spots) analysis for the overall age sex standardised TB notification rates revealed hot spots in nine district municipalities (Alfred Nzo, Thabo Mofutsanyane, uThukela, Zululand, eThekwini, ilembe, uMgungundlovu, Umzinyathi, uMkhanyakude, and uThungulu) located in three provinces (one in Eastern Cape, one in Free State, seven in KwaZulu-Natal) on the eastern side of the country. In addition, results revealed cold spots for the overall age sex standardised TB notification rates for 2010 in 11 district municipalities (Capricorn, Waterberg, Mopani, West Rand, Sedibeng, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Dr Kenneth Kaunda, Ehlanzeni, and Nkangala) located in three provinces (Gauteng, Limpopo, and Mpumalanga) in the northern part of the country. These results have a similar trend for the location of both hot and cold spots to those of the overall unadjusted TB notification rates for 2010 (see Figures 5.59 and 5.53).

Figure 5.59: *Local G Hot and Cold Spots for the Overall Age Sex Standardised Tuberculosis Notification Rates by District Municipality, 2010*
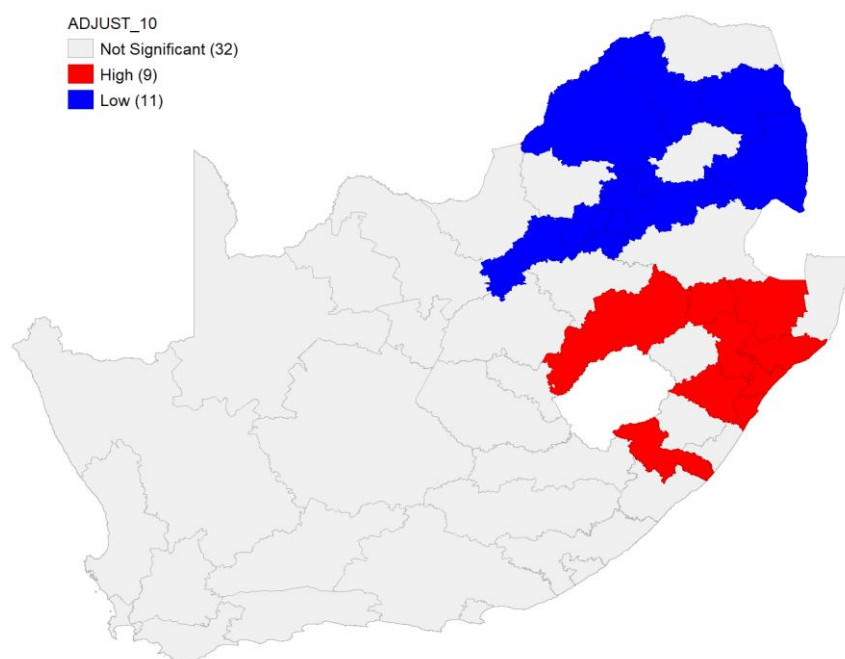
5.16.9 Age sex standardised TB notification rates for male in 2005

The results of the Local G (hot spots) analysis for 2005 for the male age sex standardised TB notification rates were similar to those of the overall age sex standardised TB notification, in that they also revealed four hot spots—two on the western part and two on the eastern part of South Africa. The western hot spots were located in Ruth S Mompati and Frances Baard district municipalities in North West and Northern Cape provinces, respectively. The eastern hot spots were located in uThungulu and uThukela in KwaZulu-Natal province. Whereas the results for the overall age sex standardised TB notification rates revealed cold spots in seven district municipalities, the ones for the male age sex standardised TB rates revealed cold spots in six district municipalities (Waterberg, Greater Sekhukhune, Bohlabela, Ehlanzeni, Metsweding, and Nkangala) located in the northern part of the country. When compared with the results of the male unadjusted TB notification rates for 2005, the results for the male age sex standardised TB notification rates revealed hot spots in KwaZulu-Natal province that were not identified with the unadjusted rates (see Figures 5.60 and 5.54).

Figure 5.60: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Male, 2005*
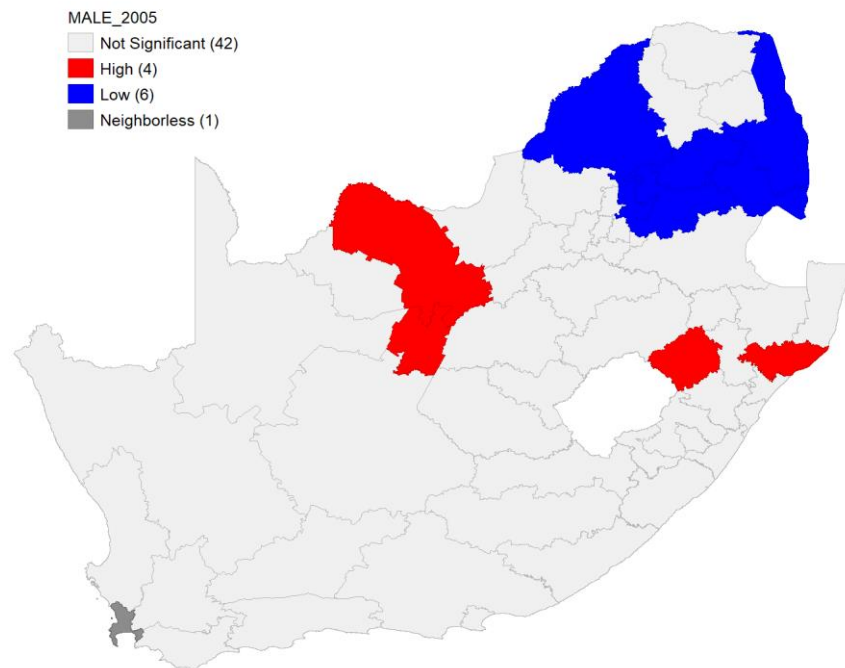
5.16.10 Age sex standardised TB notification rates for male in 2010

Results of the Local G (hot spots) analysis for the male age sex standardised TB notification rates revealed hot spots in 10 district municipalities (Alfred Nzo, Zululand, Ugu, Sisonke, eThekwini, ilembe, uMgungundlovu, Umzinyathi, uMkhanyakude, and uThungulu) located in two provinces (one in Eastern Cape and nine in KwaZulu-Natal) on the eastern side of the country. These were the same district municipalities where hot spots were identified for the overall age sex standardised and the male unadjusted TB notification rates in 2010. Again, similar to the results of the overall age sex standardised and the male unadjusted TB notification rates for 2010, these results revealed cold spots in 11 district municipalities (Capricorn, Waterberg, Mopani, West Rand, Sedibeng, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Ehlanzeni, and Nkangala) in 2010. These were located in provinces (Gauteng, Limpopo, and Mpumalanga) in the northern part of the country (see Figure 5.61).

Figure 5.61: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Male, 2010*
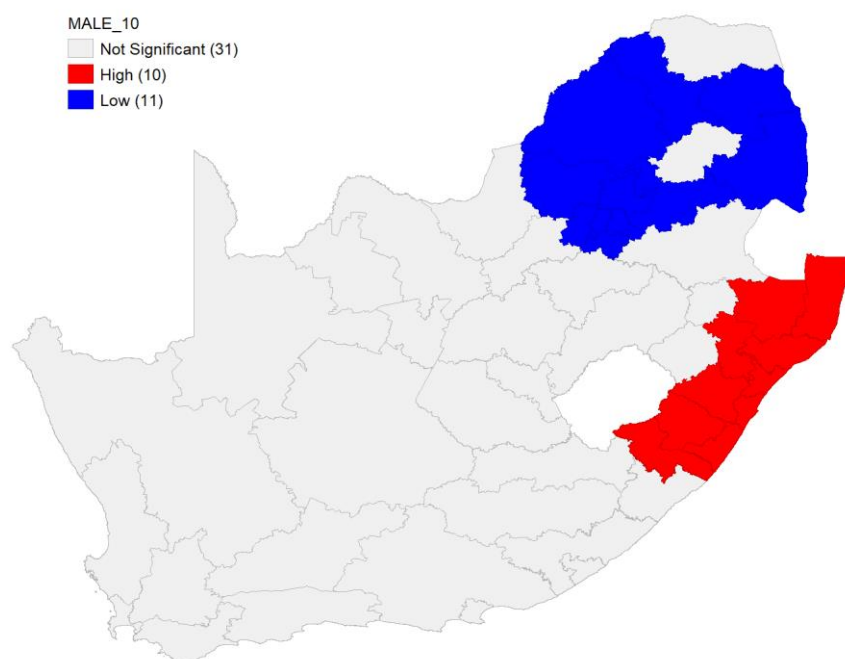
5.16.11 Age sex standardised TB notification rates for female in 2005

The results of the Local G (hot spots) analysis for 2005 for the female age sex standardised TB notification rates were somehow similar to those of the overall and male age sex standardised TB notification rates; however, in addition to the four hot spots, two more hot spots were revealed on the western part of South Africa in Namakwa and John Taolo Gaetsewe district municipalities. The ones on the western part were located in Ruth S Mompati and Frances Baard district municipalities in North West and Northern Cape provinces, respectively. The two hot spots on the eastern side of the country were located in uThungulu and uThukela in KwaZulu-Natal province. Results further revealed cold spots in seven district municipalities (Waterberg, Greater Sekhukhune, Bohlabela, Ehlanzeni, Metsweding, and Nkangala); similar to the findings of the overall age sex standardised TB notification rates. These cold spots were located in the northern part of the country. When compared with the results of the female unadjusted TB notification rates for 2005, the results for the female age sex standardised TB notification rates revealed existence of hot spots in uThungulu and uThukela district municipalities in KwaZulu-Natal province that were not identified with the unadjusted TB notification rates Local G analysis (see Figures 5.62 and 5.56).

Figure 5.62: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Female, 2005*
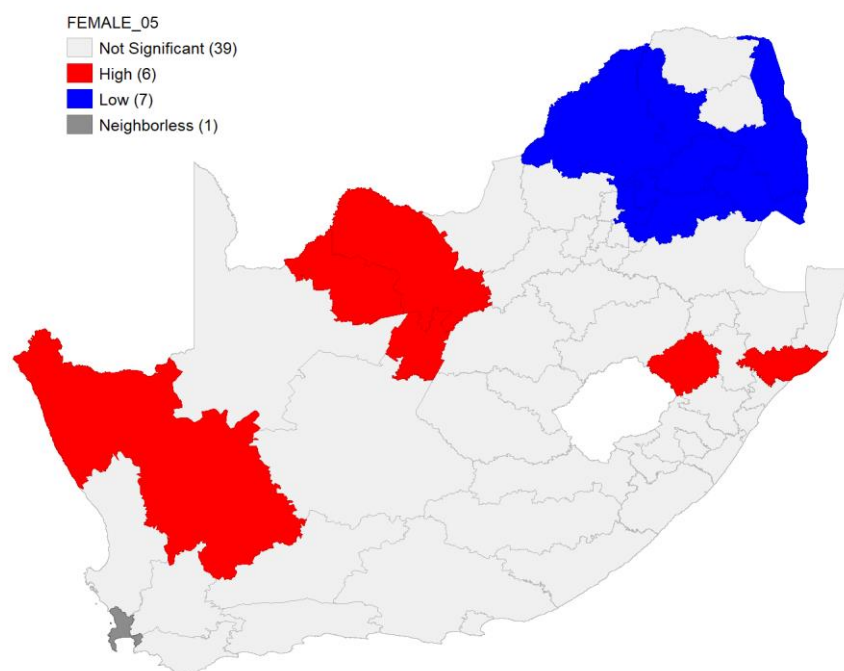
5.16.12 Age sex standardised TB notification rates for female in 2010

Results of the 2010 Local G (hot spots) analysis for the female age sex standardised TB notification rates identified hot spots in 10 district municipalities (Alfred Nzo, Zululand, Ugu, Sisonke, eThekwini, ilembe, uMgungundlovu, Umzinyathi, uMkhanyakude, and uThungulu) located in two provinces (one in Eastern Cape and nine in KwaZulu-Natal) on the eastern side of the country. Nine of these were the same district municipalities where hot spots were identified for the overall age sex standardised and the male unadjusted TB notification rates in 2010. In addition to hot spots, in 2010 the analysis identified cold spots in 11 district municipalities (Capricorn, Waterberg, Mopani, Dr Kenneth Kaunda, West Rand, Sedibeng, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Ehlanzeni, and Nkangala) located in four provinces (Gauteng, Limpopo, North West, and Mpumalanga). Three of these provinces are located in the northern part of the country, while one (North West) is in the north western section (see Figure 5.63). In comparison to the results of the Local G analysis of the female unadjusted TB notification rates of 2010, these results revealed two more cold spots one in Dr Kenneth Kaunda district municipality (North West province) and one in Sedibeng district municipality (Gauteng province).

Figure 5.63: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Notification Rates by District Municipality and Female, 2010*
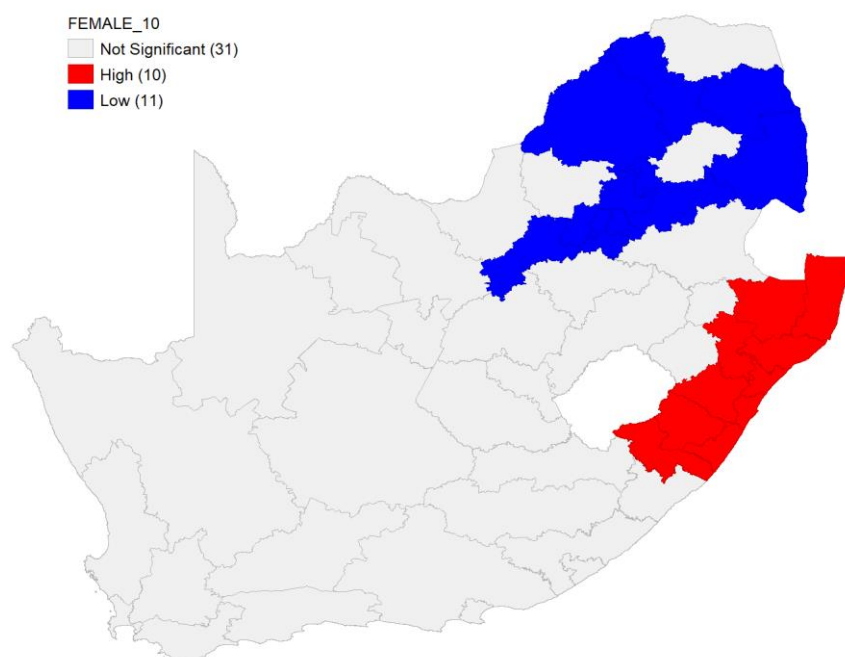

5.17 Intensity of TB death rates (hot spots)

Similarly, in this section, results of the hot spots for the TB death rates are presented beginning with those of the overall unadjusted TB death rates for 2005 and 2010. Hot spots for the unadjusted TB death rates for male for 2005 and 2010 will be presented, followed by hot spots for the unadjusted TB death rates for female for the study period. After these, hot spots for the age sex standardised TB death rates will presented, beginning with the overall, then male, and lastly hot spots for female for the period 2005 and 2010.

5.17.1 Overall unadjusted TB death rates for 2005

The Local G (hot spot) analysis for the overall unadjusted TB death rates in 2005 revealed hot spots in six district municipalities (eThekwini metropolitan, uMgungundlovu, uThukela, Amathole, Nelson Mandela metropolitan, and Ruth S Mompati). These hot spots were located on the eastern and western parts of the country in KwaZulu-Natal, Eastern Cape, and North West provinces. These results had two more hot spots in comparison to the results of the overall age sex standardised TB notification rates for 2005 and the same number of hot spots for the overall unadjusted TB notification rates; although they were not in the same district municipalities. Furthermore, results revealed cold spots in 10 district municipalities (Capricorn, Waterberg, Vhembe, Mopani, Bohlabela, Ehlanzeni, Nkangala, Greater

Sekhukhune, City of Tshwane metropolitan, and Cape Winelands). These cold spots were located in four provinces (Gauteng, Limpopo, Mpumalanga, and Western Cape) in the northern and southern parts of the country. Results revealed that a high risk of TB deaths was in the eastern and north western part of the country while a low risk was in the northern and southern parts (see Figure 5.64).

Figure 5.64: *Local G Hot and Cold Spots for the Overall Unadjusted Tuberculosis Death Rates by District Municipality, 2005*
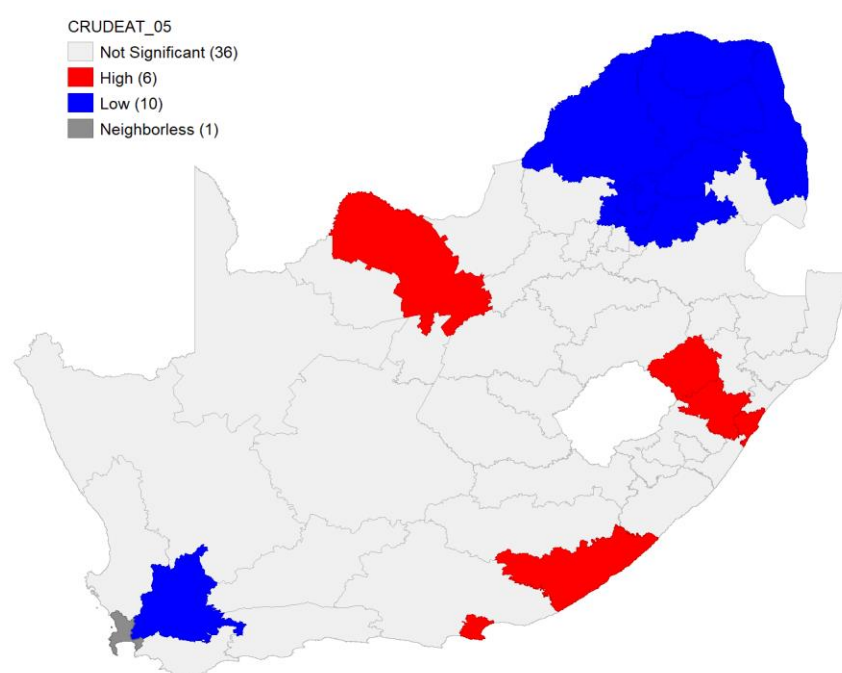
5.17.2 Overall unadjusted TB death rates for in 2010

Results of the 2010 Local G (hot spot) analysis for the overall unadjusted TB death rates revealed hot spots in nine district municipalities (Amajuba, eThekwini metropolitan, uMgungundlovu, uThungulu, Alfred Nzo, Chris Hani, Joe Gqabi, Mangaung metropolitan, and Frances Baard). These hot spots were located mostly on the eastern side part of the country in KwaZulu-Natal and Eastern Cape provinces. Furthermore, results revealed cold spots in 14 district municipalities (Capricorn, Waterberg, Mopani, Ehlanzeni, Nkangala, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, Sedibeng, West Rand, City of Cape Town metropolitan, Overberg, West Coast, and Cape Winelands), located in four provinces (Gauteng, Limpopo, Mpumalanga, and Western Cape) in the northern and southern part of the country. These results revealed that in 2010, a high risk of TB deaths was in the eastern and north western part of the country while a low risk was in the northern and southern parts (see Figure 5.65).

**Figure 5.65:** *Local G Hot and Cold Spots for the Overall Unadjusted Tuberculosis Death Rates by District Municipality, 2010*
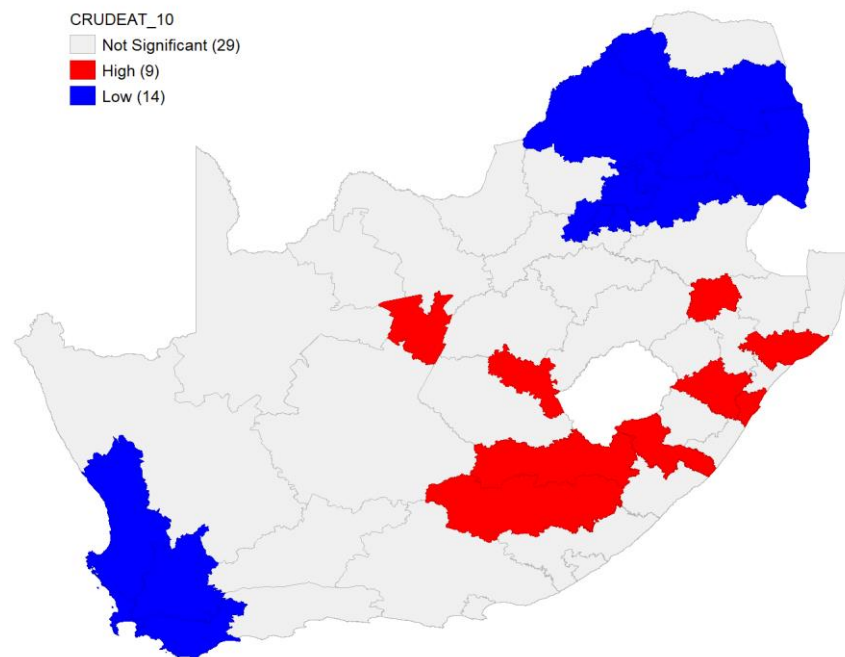
5.17.3 Unadjusted TB death rates for male in 2005

Results of the Local G (hot spots) analysis for the male unadjusted TB death rates in 2005 revealed 12 hot spots and 12 cold spots in South Africa. The 12 hot spots were located in Mangaung metropolitan, Thabo Mofutsanyane, OR Tambo, Sisonke, uMgungundlovu, eThekwini metropolitan, uThungulu, iLembe, Amajuba, Umzinyathi, Zululand, and uThukela district municipalities. These hot spots were located in three provinces (Eastern Cape, Free State, and KwaZulu-Natal) on the eastern side of the country. The 12 cold spots were located in 12 district municipalities (Cape Winelands, Eden, Ekurhuleni metropolitan, City of Tshwane metropolitan, Waterberg, Vhembe, Mopani, Bohlabela, Ehlanzeni, Nkangala, Gert Sibande, and Greater Sekhukhune) in the northern and southern parts of the country. These results revealed that in 2005, there was a high risk of TB deaths in the male population on the eastern side of the country and a lower risk in the northern and southern parts (see Figure 5.66).

Figure 5.66: *Local G Hot and Cold Spots for the Unadjusted Tuberculosis Death Rates by District Municipality and Male, 2005*
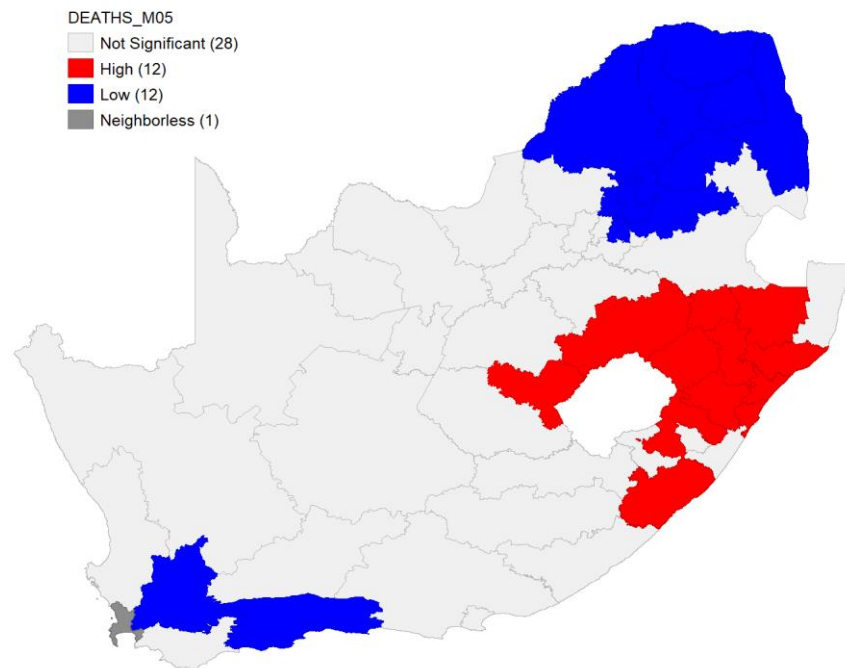
5.17.4 Unadjusted TB death rates for male in 2010

In 2010, the results of the Local G (hot spots) analysis for the male unadjusted TB death rates revealed 11 hot spots—one less than in 2005. These 11 hot spots were located in Mangaung metropolitan, Frances Baard, Alfred Nzo, Chris Hani, uMgungundlovu, eThekwini metropolitan, uThungulu, uMkhanyakude, Amajuba, Umzinyathi, and Zululand district municipalities; in three provinces (Eastern Cape, Free State, and KwaZulu-Natal) on the eastern side of the country. Results further revealed that there were 13 cold spots located in 13 district municipalities (Cape Winelands, West Coast, Overberg, Ekurhuleni metropolitan, City of Johannesburg metropolitan, City of Tshwane metropolitan, West Rand, Capricorn, Mopani, Waterberg, Sekhukhune, Ehlanzeni, and Nkangala) in the northern and southern parts of the country. They were located in four provinces (Western Cape, Gauteng, Limpopo, and Mpumalanga). Similar to the 2005 findings, the 2010 results revealed a high risk of TB deaths in the male population on the eastern side of the country and a lower risk in the northern and southern parts (see Figure 5.67).

Figure 5.67: *Local G Hot and Cold Spots for the Unadjusted Tuberculosis Death Rates by District Municipality and Male, 2010*
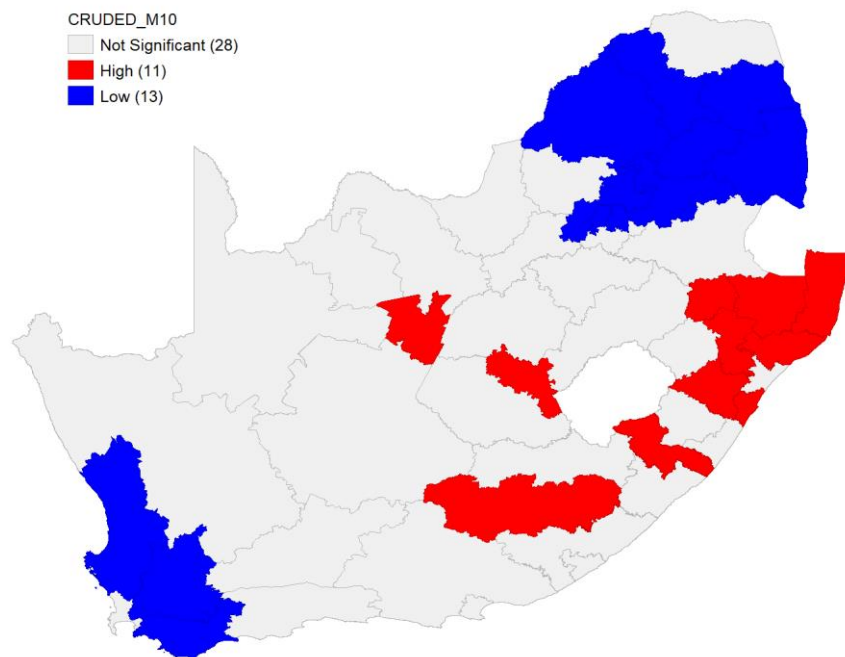
5.17.5 Unadjusted TB death rates for female in 2005

Results of the Local G (hot spots) analysis for the female unadjusted TB death rates in 2005 revealed 15 hot spots in South Africa located in Mangaung metropolitan, Thabo Mofutsanyane, Xhariep, Lejweleputswa, OR Tambo, Frances Baard, Sisonke, uMgungundlovu, eThekwini metropolitan, uThungulu, iLembe, Amajuba, Umzinyathi, Zululand, and uThukela district municipalities in three provinces (Free State, KwaZulu-Natal, and Northern Cape) on the eastern side of the country. Furthermore, results revealed 11 cold spots located in 11 district municipalities (Namakwa, Cape Winelands, Central Karoo, West Coast, Eden, Overberg, City of Tshwane metropolitan, Metsweding, Capricorn, Waterberg, and Bohlabela) in the northern and southern parts of the country in Gauteng, Limpopo, Northern Cape, and Western Cape provinces. These results revealed that in 2005 there was a high risk of TB deaths in the female population on the eastern side of the country and a lower risk in the northern and southern parts (see Figure 5.68).

Figure 5.68: *Local G Hot and Cold Spots for the Unadjusted Tuberculosis Death Rates by District Municipality and Female, 2005*
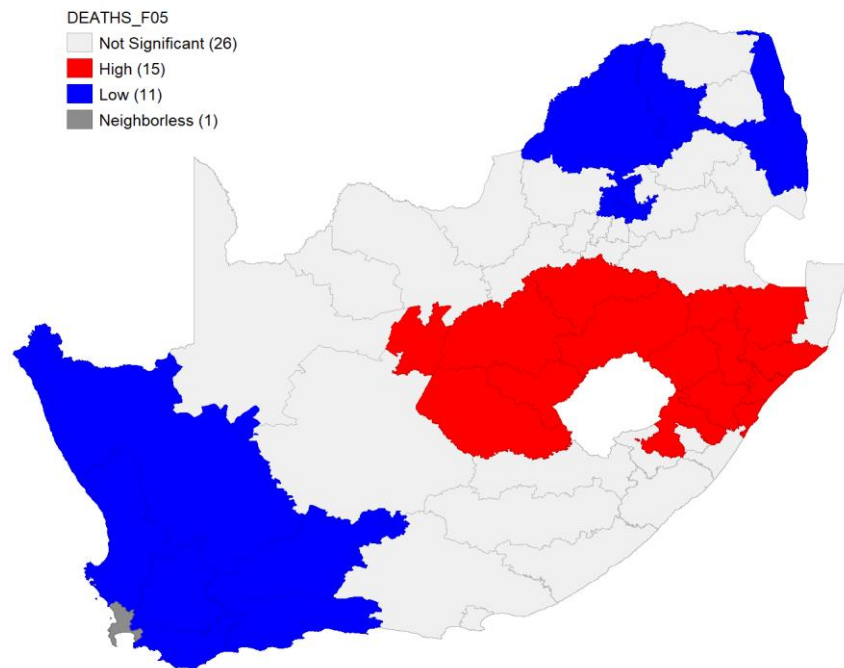
5.17.6 Unadjusted TB death rates for female in 2010

The results of the Local G (hot spots) analysis for the female unadjusted TB death rates in 2010 revealed nine hot spots and 14 cold spots in South Africa. The nine hot spots were located in Mangaung metropolitan, Chris Hani, Alfred Nzo, Frances Baard, uMgungundlovu, eThekwini metropolitan, uThungulu, Umzinyathi, and Zululand district municipalities. These hot spots were located in four provinces (Eastern Cape, Free State, KwaZulu-Natal, and Northern Cape) mainly on the eastern side of the country. The 14 cold spots identified in 2010, were located in nine district municipalities (City of Cape Town metropolitan, Cape Winelands, West Coast, Overberg, City of Tshwane metropolitan, City of Johannesburg metropolitan, Ekurhuleni metropolitan, West Rand, Capricorn, Waterberg, Mopani, Sekhukhune, Nkangala, and Ehlanzeni) in the northern and southern parts of the country in Gauteng, Limpopo, and Western Cape provinces. These results revealed that in 2010 there was a high risk of TB deaths in the female population on the eastern side of the country and a lower risk on the northern and southern parts (see Figure 5.69).

Figure 5.69: *Local G Hot and Cold Spots for The Unadjusted Tuberculosis Death Rates by District Municipality and Female, 2010*
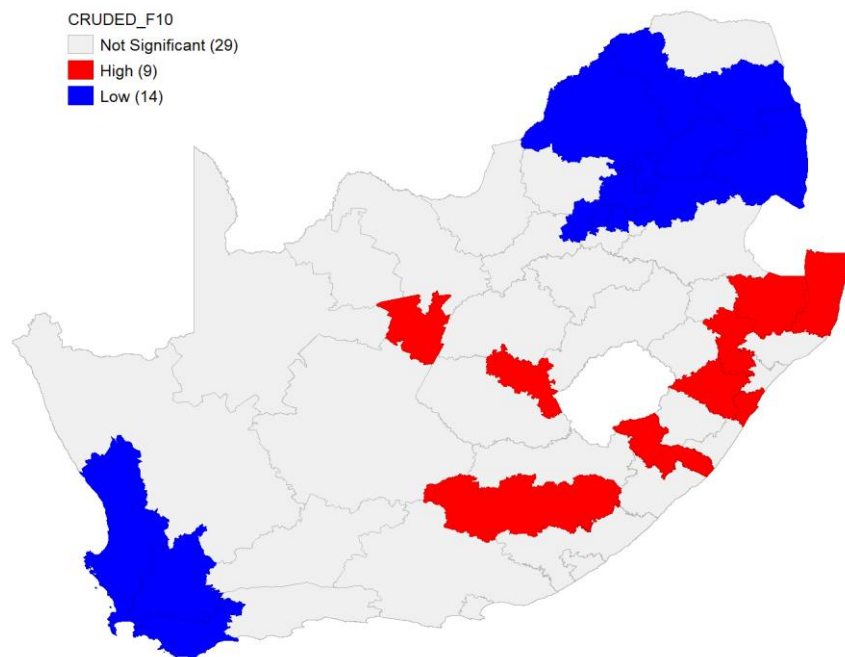
5.17.7 Overall age sex standardised TB death rates in 2005

According to the results of the Local G (hot spots) analysis for the overall age sex standardised TB death rates in 2005, 14 hot spots were identified in South Africa in the central and on the eastern side. Four of these hot spots were located in Free State province in Mangaung metropolitan, Thabo Mofutsanyane, Xhariep, and Lejweleputswa district municipalities; while one was located in OR Tambo district municipality in Eastern Cape province. The rest of the identified hot spots were in KwaZulu-Natal province in Sisonke, uMgungundlovu, eThekwini metropolitan, uThungulu, iLembe, Amajuba, Umzinyathi, Zululand, and uThukela district municipalities. Furthermore, results revealed presence of 11 cold spots located in 11 district municipalities. One cold spot was located in Northern Cape province in Namakwa district municipality; whereas four cold spots were identified in Western Cape province in Cape Winelands, Central Karoo, West Coast, and Eden district municipalities. In addition, three cold spots were located in Gauteng province in the City of Tshwane metropolitan, Ekurhuleni metropolitan, and Metsweding district municipalities; and another three in Limpopo province in Capricorn, Waterberg, and Bohlabela district municipalities. Results of the overall age sex standardised TB death rates in 2005, revealed a high risk of TB deaths in the South African population on the eastern and central parts of the country and a lower risk in the northern and southern parts (see Figure 5.70).

Figure 5.70: *Local G Hot and Cold Spots for the Overall Age Sex Standardised Tuberculosis Death Rates by District Municipality, 2005*
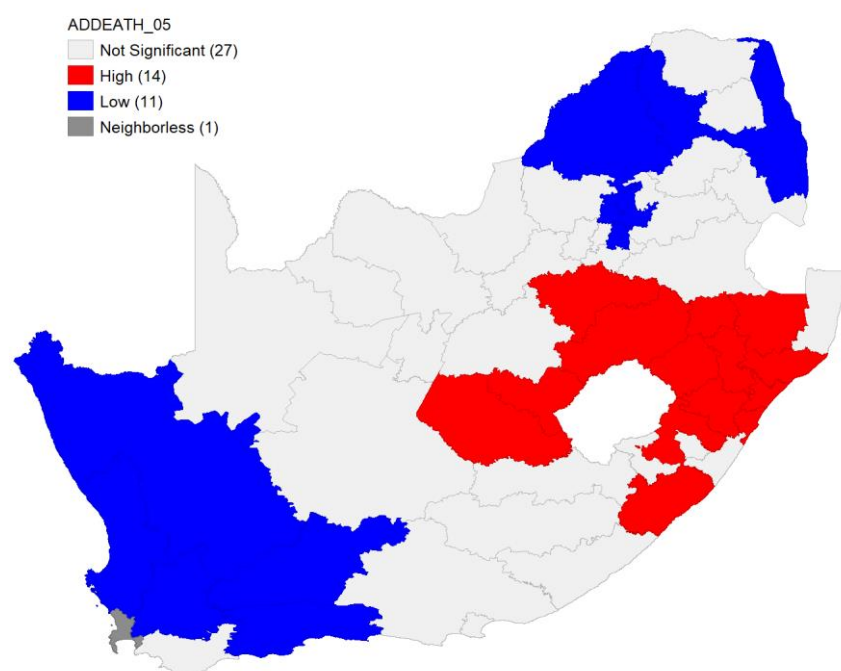
5.17.8 Overall age sex standardised TB death rates in 2010

Six hot spots were identified in South Africa by the Local G (hot spots) analysis for the overall age sex standardised TB death rates in 2010. These hot spots were on the eastern side of the country located in three provinces. One hot spot was identified in Free State province in Thabo Mofutsanyane district municipality, and another was located in Eastern Cape province in Chris Hani district municipality. All other hot spots were identified in KwaZulu-Natal province in Amajuba, uMgungundlovu, Umzinyathi, and uThukela district municipalities. According to this hot spots analysis, 12 cold spots were located in 12 district municipalities across the country—four in Western Cape province in the City of Cape Town metropolitan, Cape Winelands, Overberg, and West Coast district municipalities; four located in Gauteng province in the City of Johannesburg metropolitan, City of Tshwane metropolitan, Ekurhuleni metropolitan, and West Rand district municipalities; two in Limpopo province in Capricorn and Waterberg district municipalities; and one each in North West province in Bojanala district municipality and Nkangala district municipality in Mpumalanga province. In other words, results revealed a high risk of TB deaths in 2010 in the South African population on the eastern part of the country with a lower risk in the northern and southern parts (see Figure 5.71).

Figure 5.71: *Local G Hot and Cold Spots for the Overall Age Sex Standardised Tuberculosis Death Rates by District Municipality, 2010*
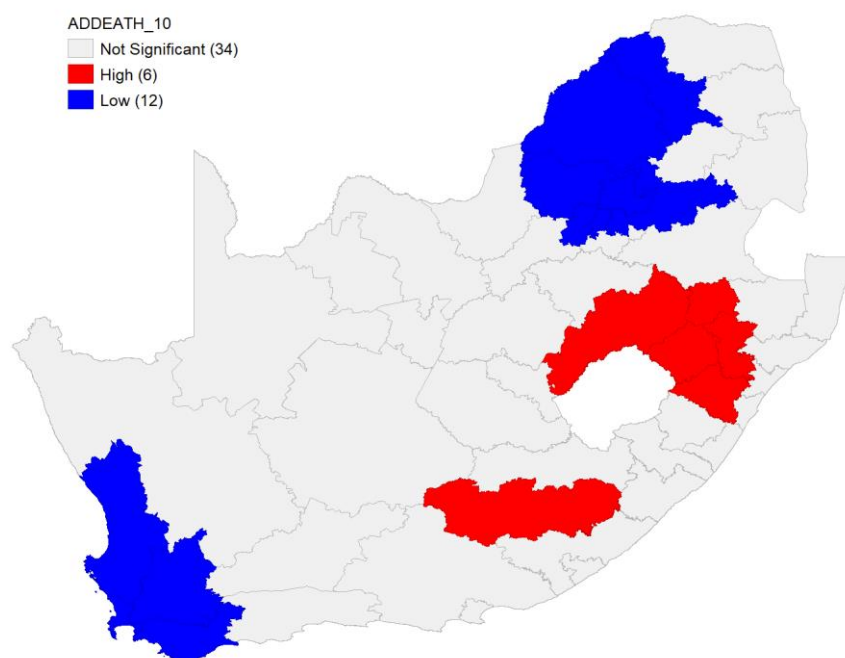
5.17.9 Age sex standardised TB death rates for male in 2005

The 2005 results of the Local G (hot spots) analysis for the male age sex standardised TB death rates identified 12 hot spots on the eastern side of South Africa. Free State province had two of the hot spots located in Mangaung metropolitan and Thabo Mofutsanyane district municipalities. In Eastern Cape province there was one hot spot located in OR Tambo district municipality. The majority of hot spots were identified in KwaZulu-Natal province in Sisonke, uMgungundlovu, eThekwini metropolitan, uThungulu, iLembe, Amajuba, Umzinyathi, Zululand, and uThukela district municipalities. In addition to hot spots, results identified a presence of 12 cold spots. Two cold spots were identified in Western Cape province in Cape Winelands and Eden district municipalities. Four cold spots were in Limpopo province in Capricorn, Waterberg, Vhembe, and Bohlabela district municipalities; Mpumalanga province had one cold spot in Nkangala district municipality; and the remaining cold spots were located in Gauteng province in the City of Tshwane metropolitan, Ekurhuleni metropolitan, and Metsweding district municipalities. These results mean that in 2005 there was a higher risk of TB deaths in the male population on the eastern part of South Africa and a lower risk in the northern and southern parts (see Figure 5.72).

Figure 5.72: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Male, 2005*
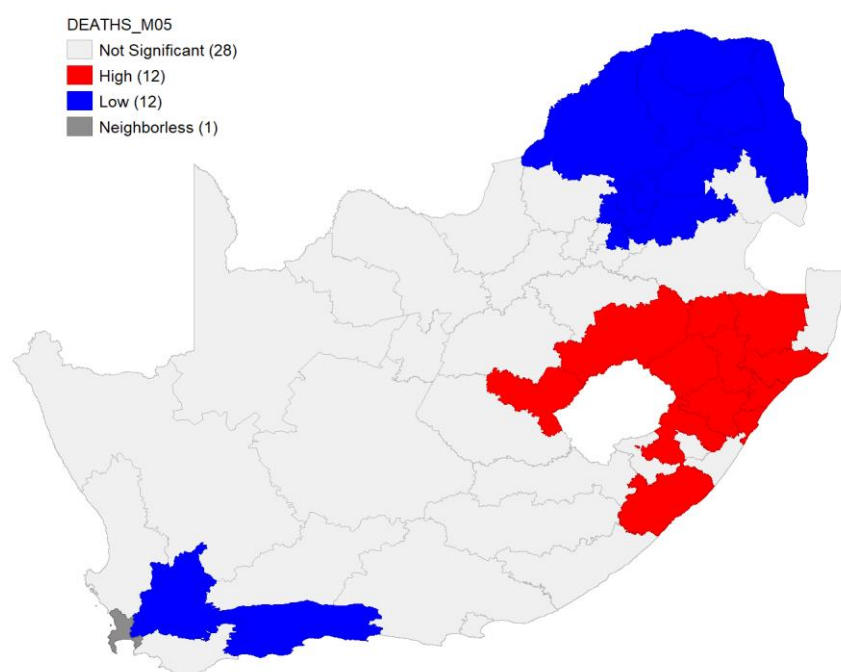
5.17.10 Age sex standardised TB death rates for male in 2010

In 2010, the Local G hot spots analysis identified 10 hot spots for the male age sex standardised TB death rates. These hot spots were located in the central part with the majority on the eastern side of the country. In Free State province there was one hot spot located in Mangaung metropolitan municipality, while the other one was located in Frances Baard district municipality in Northern Cape province. Two hot spots were in Eastern Cape province, in Joe Gqabi and Chris Hani district municipalities. The rest were in KwaZulu-Natal province in uMgungundlovu, uThungulu, Amajuba, Umzinyathi, Zululand, and uThukela district municipalities. Analysis further revealed a presence of 13 cold spots in 13 district municipalities in the country: one cold spot in North West province in Bojanala district municipality; four in Western Cape province in the City of Cape Town metropolitan, Cape Winelands, Overberg, and West Coast district municipalities; five in Gauteng province in the City of Johannesburg metropolitan, City of Tshwane metropolitan, Ekurhuleni metropolitan, Sedibeng, and West Rand district municipalities; two in Limpopo province in Capricorn and Waterberg district municipalities; and one cold spot in Nkangala district municipality in Mpumalanga province. These results indicate that, in 2010, there was a high risk of TB deaths

in the male in the South African population on the eastern and central parts of the country and a lower risk in the northern and southern parts (see Figure 5.73).

Figure 5.73: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Male, 2010*
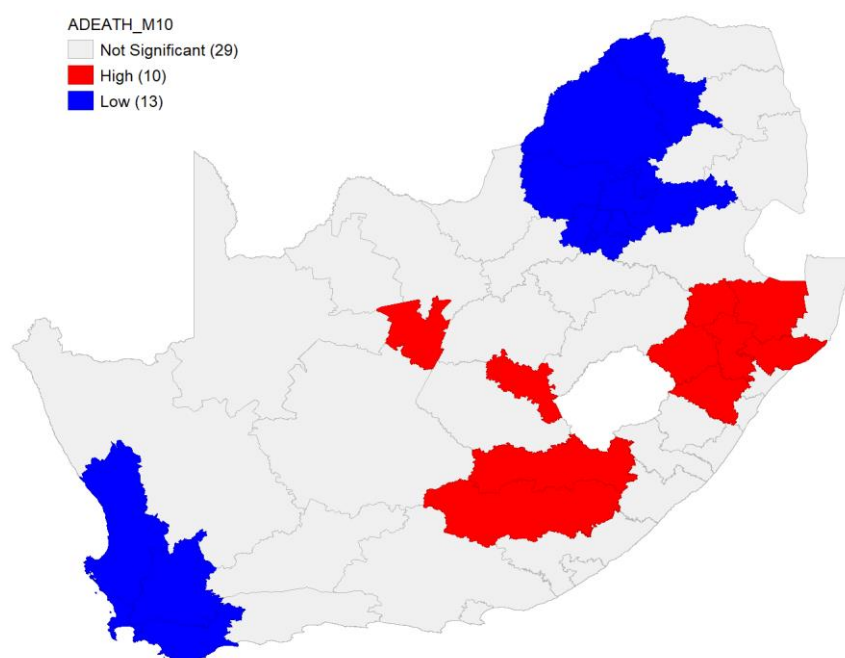
5.17.11 Age sex standardised TB death rates for female in 2005

The Local G hot spots analysis for the female age sex standardised TB death rates in 2005, identified 15 hot spots in the central and on the eastern side of South Africa. In Free State province there were four hot spots located in Mangaung metropolitan, Thabo Mofutsanyane, Xhariep, and Lejweleputswa district municipalities; while one was located in Frances Baard district municipality in Northern Cape province. The majority of hot spots were identified in KwaZulu-Natal province in Sisonke, uMgungundlovu, eThekwini metropolitan, uThungulu, iLembe, Amajuba, Umzinyathi, Zululand, and uThukela district municipalities. In addition, results identified a presence of 11 cold spots in the country. One cold spot was located in Northern Cape province in Namakwa district municipality; four identified in Western Cape province in Cape Winelands, Central Karoo, West Coast, and Eden district municipalities; two cold spots were located in Gauteng province in the City of Tshwane metropolitan and Metsweding district municipalities; and a further three cold spots identified in Limpopo province in Capricorn, Waterberg, and Bohlabela district municipalities. Consequently, the results of the Local G analysis for the female age sex standardised TB death rates in 2005

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indicated a higher risk of TB deaths in the female population on both the eastern and central parts of the country, with a lower risk on the northern and southern parts (see Figure 5.74).

Figure 5.74: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Female, 2005*
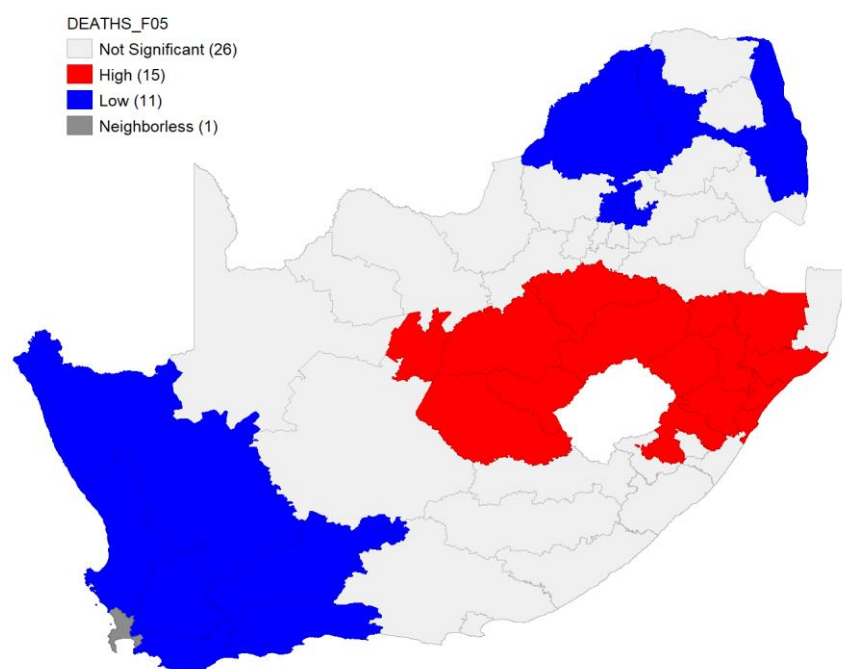
5.17.12 Age sex standardised TB death rates for female in 2010

During 2010, there were seven hot spots for the female age sex standardised TB death rates identified by the Local G hot spots analysis. The majority of hot spots were located on the eastern side of the country with one in the central part in Frances Baard district municipality in Northern Cape province and the other in Free State province located in Mangaung metropolitan municipality. There were two hot spots identified in Eastern Cape province, located in Chris Hani and Joe Gqabi district municipalities. The other hot spots were in KwaZulu-Natal province in Amajuba, Umzinyathi, and uThungulu district municipalities. Analysis further revealed a presence of 10 cold spots in the country—four were identified in Western Cape province in the City of Cape Town metropolitan, Cape Winelands, Overberg, and West Coast district municipalities; four were identified in Gauteng province in the City of Johannesburg metropolitan, City of Tshwane metropolitan, Ekurhuleni metropolitan, and West Rand district municipalities; and two cold spots were identified in Limpopo province in Capricorn and Waterberg district municipalities. Similar to the 2005 results, these results indicated that in 2010 there was a higher risk of female TB deaths in the eastern and central parts of the country than there was in the northern and southern parts (see Figure 5.75).

Figure 5.75: *Local G Hot and Cold Spots for the Age Sex Standardised Tuberculosis Death Rates by District Municipality and Female, 2010*
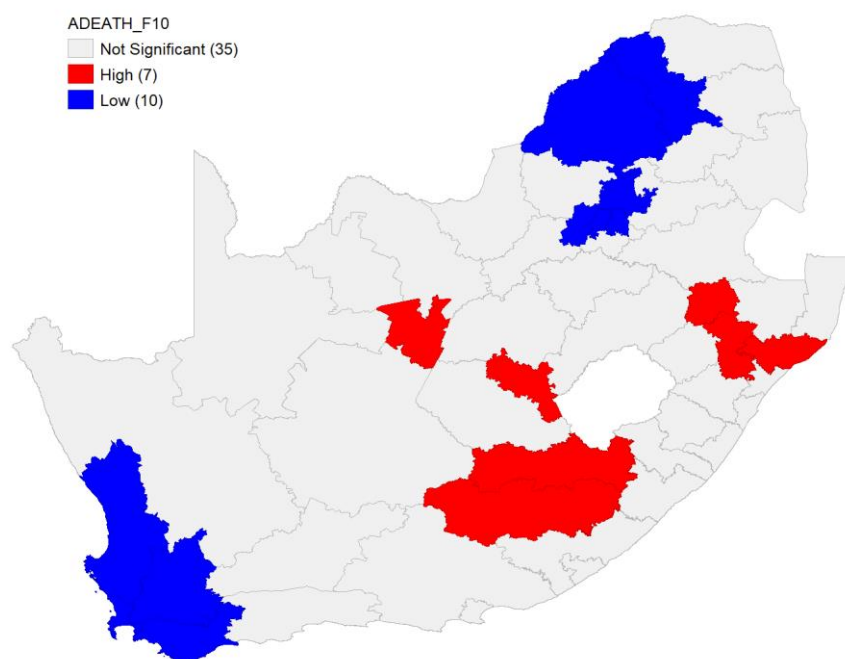
5.18 The South African Multidimensional Poverty Index

In this section, results of the SAMPI for 2001 and 2011 will be presented. The 2001 results will be presented first followed by the 2011 results.

5.18.1 The SAMPI, 2001

In 2001, there were 13 district municipalities that had the highest levels of SAMPI [0.119 : 0.196]. Two district municipalities were located on the north western part of the country— John Taolo Gaetsewe district municipality (Northern Cape province) and Ruth S Mompati district municipality (North West province). Those that were located on the eastern side of South Africa were uMkhanyakude, iLembe, Zululand, uThukela, Umzinyathi, Ugu, and Sisonke (KwaZulu-Natal province); and Alfred Nzo, Amathole, Joe Gqabi, OR Tambo, and Chris Hani district municipalities (Eastern Cape province). All district municipalities in Western Cape province, some in Northern Cape and Gauteng provinces had the lowest levels of SAMPI [0.016 : 0.0555] in 2001 (see Figure 5.76).

Figure 5.76: *South African Multidimensional Poverty Index by District Municipality, 2001*
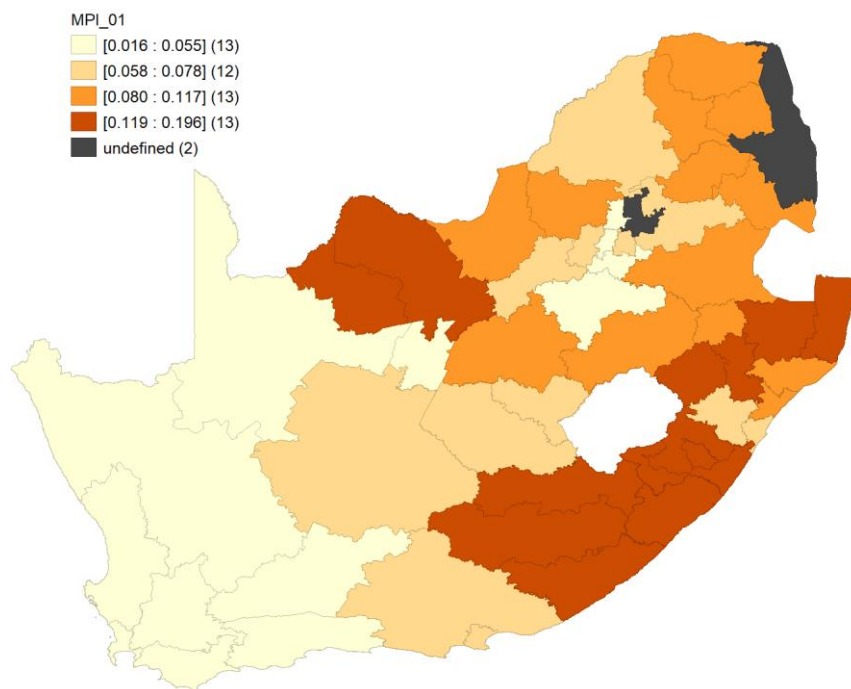
5.18.2 The SAMPI, 2011

There were 10 district municipalities with high levels of SAMPI [0.058 : 0.107] in 2011 which were located on the eastern part of the country in two provinces. These district municipalities were uMkhanyakude, uThukela, Umzinyathi, Ugu, and Sisonke (KwaZulu-Natal province); and the rest were Alfred Nzo, Amathole, Joe Gqabi, OR Tambo, and Chris Hani district municipalities (Eastern Cape province). Similar to 2001, all district municipalities in Western Cape province and some in Northern Cape and Gauteng provinces had the lowest levels of SAMPI [0.008 : 0.018] in 2011 (see Figure 5.77).

Figure 5.77: *South African Multidimensional Poverty Index by District Municipality, 2011*
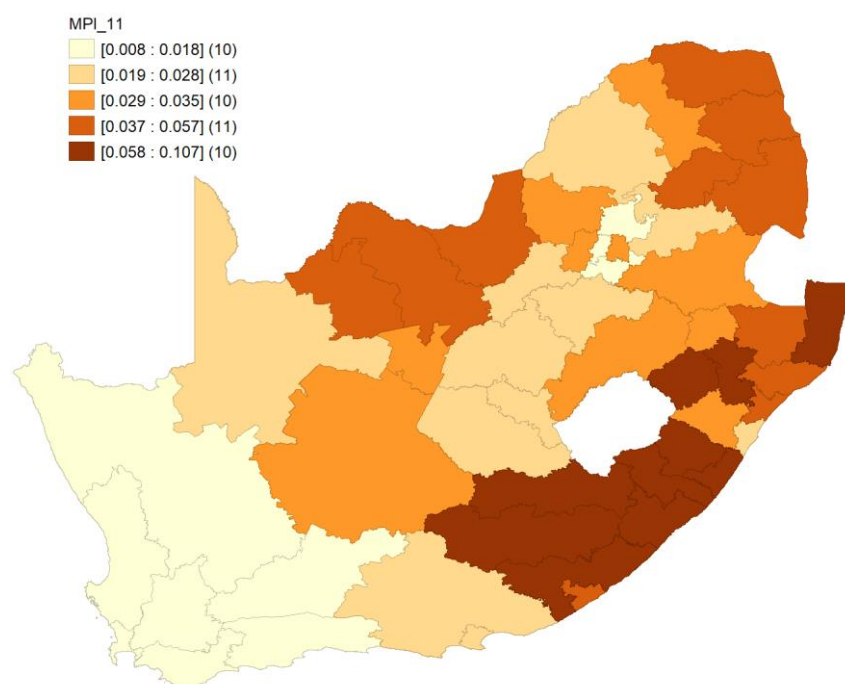
5.19 The HIV prevalence in South Africa in 2010

In 2010, there were 10 district municipalities that had the highest prevalence [37 : 42.3] of HIV in South Africa. Seven of these district municipalities (uMkhanyakude, Zululand, iLembe, eThekwini metropolitan, Ugu, Sisonke, and uMgungundlovu) were in KwaZulu-Natal province; while two (Gert Sibande and Ehlanzeni) were in Mpumalanga province and only one (Dr Kenneth Kaunda) in North West province. Most of these district municipalities were located on the eastern and north eastern part of the country. There were 10 district municipalities with the lowest prevalence [8.5 : 18.7]. Of these, five district municipalities (Cape Winelands, Central Karoo, Eden, and Overberg) were in Western Cape province, while three (Namakwa, Pixley ka Seme, and Siyanda) were in Northern Cape province. Free State and Limpopo provinces had one district municipality each (Xhariep and Vhembe respectively) (see Figure 5.78).

Figure 5.78: *Prevalence of the Human Immunodeficiency Virus in South Africa by District Municipality, 2010*
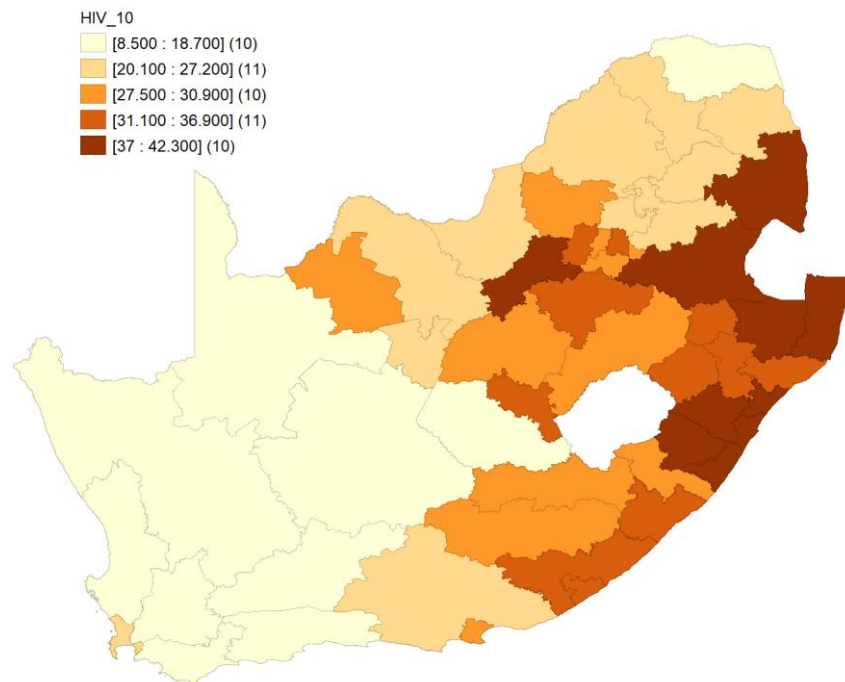
5.20 Spatial dependency analysis

In this section, results of the spatial lag regression analysis for the 2010 TB age sex standardised notification and death rates are presented. The results of the overall age sex standardised TB notification rates will be presented first, followed by the results for the male age sex standardised and then the female age sex standardised TB notification rates. Finally, the overall age sex standardised TB death rates will be presented followed by those of the male age sex standardised and female age sex standardised TB death rates.

5.20.1 Spatial lag regression for the overall age sex standardised TB notification rates

Results of the spatial lag regression analysis for the overall age sex standardised TB notification rates revealed a positive association between the overall standardised age sex TB notification rates for both HIV and SAMPI in the neighbouring district municipalities. However, this association was not statistically significant at p values 0.12808 and 0.46870 for HIV and SAMPI respectively (see Table 5.9).

Table 5.9: *Spatial Lag Regression Coefficient, Std Error, Z, and P-Values for The Overall Age Sex Standardised Tuberculosis Notification Rates, 2010*

Variable	Coefficient	Std. Error	Z value	p-value
W_ADJUST_10	0.534216	0.135163	3.95239	0.00008
CONSTANT	77.1751	272.433	0.283281	0.77696
HIV_10	15.8013	10.3838	1.52173	0.12808
SAMPI_11	2656.96	3666.78	0.724601	0.46870

5.20.2 Spatial lag regression for the male age sex standardised TB notification rates

Results of the spatial lag regression analysis for the male age sex standardised TB notification rates of 2010, revealed a positive association between the male age sex standardised TB notification rates for both HIV and SAMPI in the neighbouring district municipalities. However, this association was not statistically significant at p values 0.15785 and 0.47454 for HIV and SAMPI respectively (see Table 5.10).

Table 5.10: *Spatial Lag Regression Coefficient, Std Error, Z and P-Values for the Male Age Sex Standardised Tuberculosis Notification Rates, 2010*

Variable	Coefficient	Std. Error	Z value	p-value
W_MALE_10	0.619038	0.119412	5.18406	0.00000
CONSTANT	96.5584	240.600	0.401324	0.68818
HIV_10	12.7305	9.01372	1.41235	0.15785
SAMPI_11	2279.28	3187.29	0.715116	0.47454

5.20.3 Spatial lag regression for the female age sex standardised TB notification rates

Spatial lag regression analysis for the female age sex standardised TB notification rates demonstrated a presence of a positive association between the female age sex standardised TB notification rates for both HIV and SAMPI in the neighbouring district municipalities. However, this association was not statistically significant at p values 0.10857 and 0.90081 for HIV and SAMPI respectively (see Table 5.11).

Table 5.11: *Spatial Lag Regression Coefficient, Std Error, Z and P-Values for the Female Age Sex Standardised Tuberculosis Notification Rates, 2010*

Variable	Coefficient	Std. Error	Z value	p-value
W_FEMALE_10	0.644489	0.114239	5.64160	0.00000
CONSTANT	73.5434	187.926	0.391343	0.69554
HIV_10	11.2626	7.01878	1.60464	0.10857
SAMPI_11	307.119	2463.96	0.124644	0.90081

5.20.4 Spatial lag regression for the overall age sex standardised TB death rates

Spatial lag regression analysis for the overall age sex standardised TB death rates identified a positive association between the overall age sex standardised TB death rates for both HIV and SAMPI in the neighbouring district municipalities. The association between the overall age sex standardised TB death rates for both HIV and SAMPI were not statistically significant at p values 0.49995 and 0.05887 respectively (see Table 5.12).

Table 5.12: *Spatial Lag Regression Coefficient, Std Error, Z and P-Values for the Overall Age Sex Standardised Tuberculosis Death Rates, 2010*

Variable	Coefficient	Std. Error	Z value	p-value
W_ADDEATH_10	0.418345	0.15308	2.73285	0.00628
CONSTANT	34.9371	49.247	0.709427	0.47806
HIV_10	1.22123	1.80868	0.675205	0.49955
SAMPI_11	1262.73	668.402	1.88918	0.05887

5.20.5 Spatial lag regression for the male age sex standardised TB death rates

The spatial lag regression analysis for the male age sex standardised TB death rates revealed a positive association between the male age sex standardised TB death rates for both HIV and SAMPI in the neighbouring district municipalities. The association between the male age sex standardised TB death rates with HIV was not statistically significant at p value 0.73237. However, the association with SAMPI was statistically significant at p value 0.01727 (see Table 5.13).

Table 5.13: *Spatial Lag Regression Coefficient, Std Error, Z and P-Values for the Male Age Sex Standardised Tuberculosis Death Rates, 2010*

Variable	Coefficient	Std. Error	Z value	p-value
W_ADEATH_M10	0.47336	0.143263	3.30414	0.00095
CONSTANT	47.1193	45.256	1.04117	0.29780
HIV_10	0.549491	1.60684	0.34197	0.73237
SAMPI_11	1437.1	603.592	2.38092	0.01727

5.20.6 Spatial lag regression for the female age sex standardised TB death rates

The spatial lag regression analysis for the female age sex standardised TB death rates revealed a positive association between the female age sex standardised TB death rates for both HIV and SAMPI in the neighbouring districts. The association between the female age sex standardised TB death rates and HIV and SAMPI were both not statistically significant at p values 0.58862 and 0.06040 for HIV and SAMPI respectively (see Table 5.14).

Table 5.14 : *Spatial Lag Regression Coefficient, Std Error, Z and P-Values for the Female Age Sex Standardised Tuberculosis Death Rates, 2010*

Variable	Coefficient	Std. Error	Z value	p-value
W_ADEATH_F10	0.441217	0.149964	2.94215	0.00326
CONSTANT	38.7686	36.3154	1.06755	0.28572
HIV_10	0.695831	1.2866	0.540831	0.58862
SAMPI_11	896.103	477.189	1.87788	0.06040

5.2 Summary

This chapter has presented results of the geospatial patterns of TB in South Africa in 2005 and 2010. Results showed that some district municipalities, particularly Dr Kenneth Kaunda, uMkhanyakude, and Ugu, had higher TB notification rates than others. Further, the study identified Cacadu, Xhariep, uMkhanyakude, and Ugu as the district municipalities with the highest TB death rates. The study identified a positive association between TB notifications, TB deaths, SAMPI, and HIV. Other findings were a spatial autocorrelation in the TB notification and death data for 2005 and 2010. Furthermore, this study underscored the utility of the GIS and demonstrated a presence of hot spots for the overall, male and female, for the crude and age sex standardised TB notification and death rates in 2005 on the north western

part and in 2010 in the eastern region of South Africa. Findings from this study further confirm the hypothesis that there is a geographical variation in TB notification and death rates across South Africa. These findings are important for consideration by the South African TB programme managers, at all levels of the health system, when formulating targeted TB interventions such as aggressive detection of TB cases in vulnerable populations, followed by initiating them early to treatment and follow up to ensure that treatment is completed. The next chapter presents findings of the concordance between ART and TB.

Chapter 6 – Results: Concordance between Antiretroviral Treatment and Tuberculosis

6.0 Introduction

The previous chapter presented results of the geospatial analysis. This chapter presents results of the analysis, by the plotting of graphs, for the concordance between ART coverage and TB. The hypothesis for this analysis was: High ART uptake will have reduced TB related mortality. The chapter begins with presenting the raw data for the number of people on ART and the estimated number of people who were living with HIV in South Africa for the period 2004-2015. This is followed by results of the analysis of TB case notification rates and ART coverage, and then the results of the analysis of TB deaths from the mortality data and ART coverage, and analysis of TB deaths from the ETR and ART coverage. Furthermore, analysis of TB/HIV co-infection case notifications and ART coverage is presented. The chapter concludes with a summary of the content.

Raw data for the number of people on ART, accessed from the Department of Health, and the total number of those people that are living with HIV in South Africa for the period 2004-2015 are presented in Table 6.1. The data shows there was substantial increase in the percentage and total number of people put on ART in South Africa from 0.0004% (18) in 2004 to 44.6% (3 212 382) in 2015. Similarly, there was an increase in the estimated number of people living with HIV in South Africa from 4 700 000 in 2004 to 7 200, 000 in 2015.

6.1 TB case notification rates and ART coverage

The data for people on ART were available for the period 2004-2015; however, the analysis was done by plotting graphs for the period 2005-2012 because this is the period for which TB notification data were available. Figure 6.1 shows that as the TB notification rates increased from 2005 to 2009 (689.2 to 1 078.7 per 100 000), similarly ART coverage increased. After 2009, there was a decrease in TB notification rates (1 078.7 to 928.3 per 100 000) that was observed with yet another increase in 2011 (928.3 to 991.7 per 100 000). Throughout this time, ART coverage continued to increase: 0.1% to 32.9% for 2005 and 2012 respectively; and alongside, a decrease in TB notification rates was observed again in 2012 (991.7 to 835.5 per 100 000).

Table 6.1: *Antiretroviral Treatment Raw and Coverage Data and People Living with the Human Immunodeficiency Virus Raw Data by Year, South Africa 2004-2015*

Year	Number of people on ART in South Africa	Estimates of number of people living with HIV in South Africa ('100, 000)	ART coverage (%)
2004	18	4,7	0.0
2005	5,524	5,0	0.1
2006	38,123	5,5	0.7
2007	84,716	5,4	1.6
2008	162,895	5,6	2.9
2009	517,272	5,9	8.8
2010	798,673	6,1	13.1
2011	1,438,220	6,4	22.5
2012	2,168,613	6,6	32.9
2013	2,629,980	6,8	38.5
2014	2,921,226	7,0	41.6
2015	3,212,382	7,2	44.6

Figure 6.1: *Trends in Tuberculosis Case Notification Rates and Antiretroviral Treatment Coverage, 2005-2012*
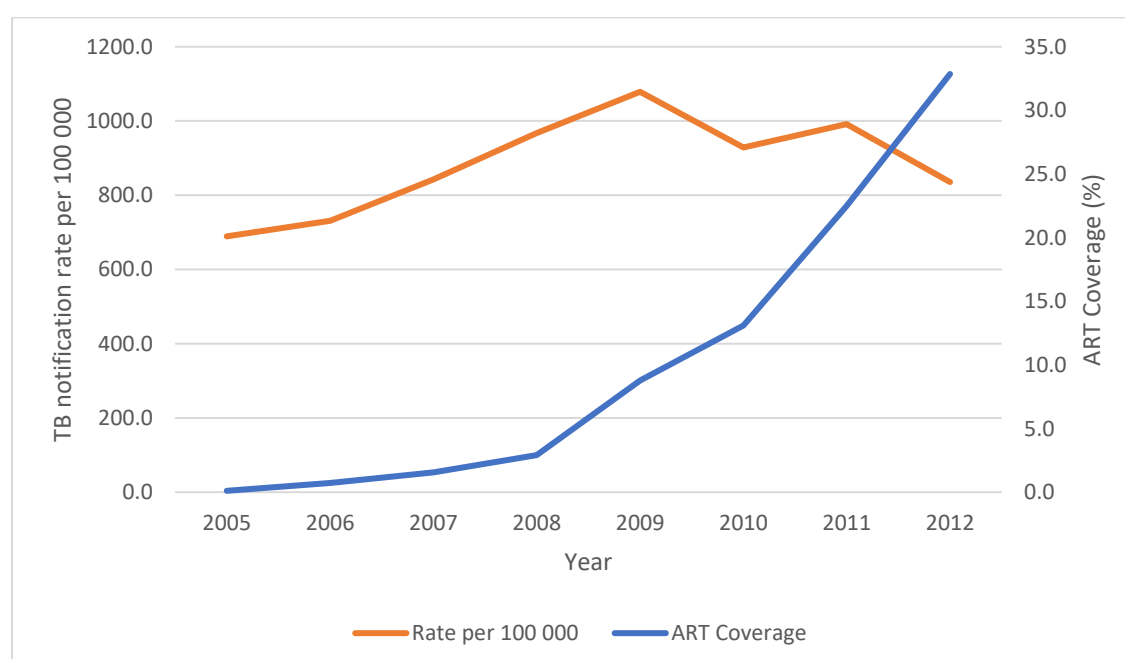
6.2 TB deaths from the mortality data and ART coverage

This analysis was done by plotting a graph for the period 2005-2015 because both the ART data and the TB deaths data from the mortality data set were available for that period. Plotting the proportion of TB deaths (from the TB mortality data) and ART coverage showed an inverse trend in the declining proportion of TB deaths with increasing coverage of ART from 2005 to 2015. It was, therefore, observed that the highest ART coverage was in 2015 with a corresponding low proportion of TB deaths at 44.6% and 59.5% per 100 000 for ART coverage and proportion of TB deaths, respectively. Similarly, in 2005, the highest proportion of TB deaths observed corresponded with low ART coverage at 178.9 per 100 000 and 0.1% for proportion of TB deaths and ART coverage respectively (see Figure 6.2).

Figure 6.2: *Trends for the Proportion of Tuberculosis Death Rates per 100 000 and Antiretroviral Treatment Coverage, 2005-2015*
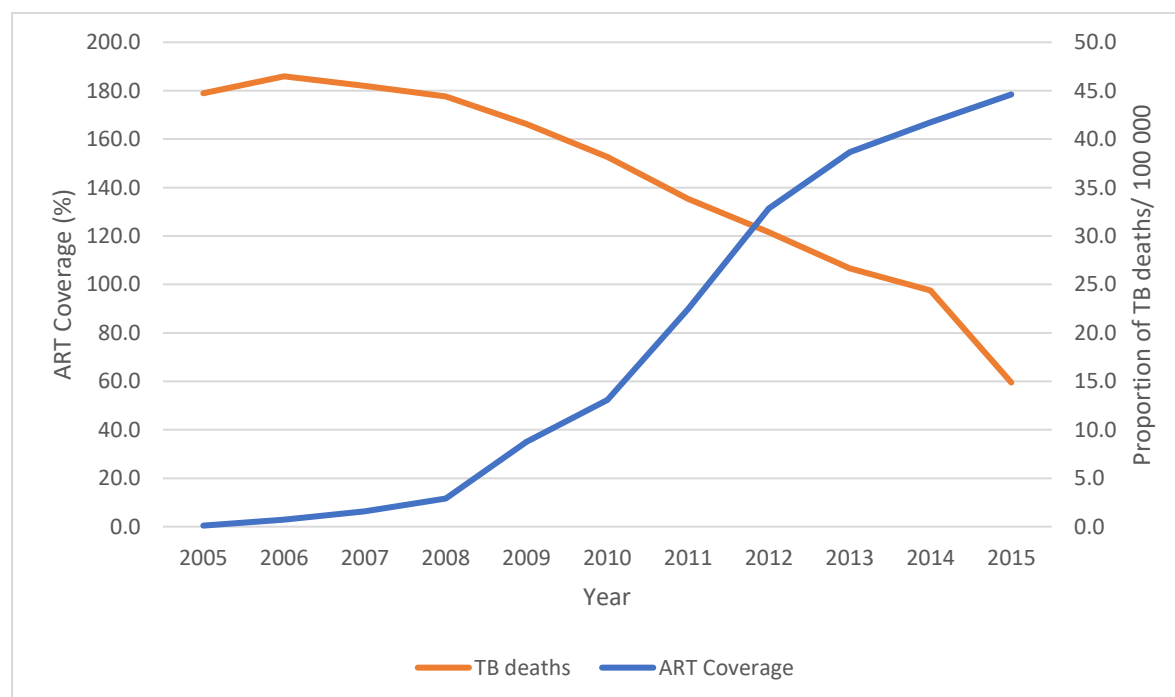
6.3 TB deaths from the ETR data and ART coverage

The data used for this analysis was for the period 2005-2012, as the TB deaths that were retrieved from the ETR data were only available for that period. Plotting the proportion of TB deaths from the ETR data with ART coverage showed similar trends to those of plotting the proportion of TB deaths (from the TB mortality data) and ART coverage, especially from 2008 onwards. The plot showed an inverse trend in the declining proportion of TB deaths with increasing coverage of ART from 2008 to 2012. This means that the highest ART coverage for the study period was observed during 2012 while the lowest proportion of TB deaths was

observed in the same year at 32.9% and 4.4% for the ART coverage and proportion of TB deaths, respectively. Contrary to what was observed with the plotting of TB deaths from the mortality data and ART coverage, the highest TB deaths (8.0%) from the ETR data were observed in 2008, while the lowest ART coverage (0.1%) was observed in 2005 (see Figure 6.3).

Figure 6.3: *Trends for the Proportion of the Electronic Tuberculosis Register Tuberculosis Deaths and Antiretroviral Treatment Coverage, 2005-2012*
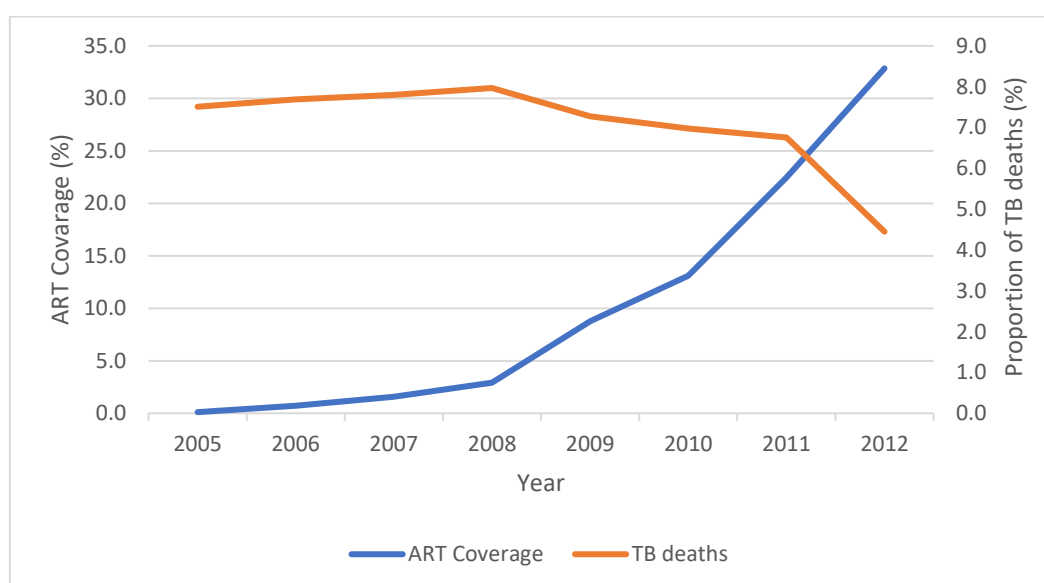
6.4 TB/HIV co-infection case notifications and ART coverage

Analysis by plotting TB/HIV co-infection case notifications with ART coverage revealed that both indicators increased from 2005 to 2012 (3.9% to 54.9% for TB/HV co-infection case notifications and 0.1% to 22.5% for ART coverage) with a further increase for ART coverage beyond the year 2012. The highest observed percentage for both TB/HIV co-infection case notifications and ART coverage was in 2012 at 54.9% and 32.9% respectively. The lowest percentages for both indicators were observed in 2005 at 3.9% for TB/HIV co-infection case notifications and 0.1% for ART coverage (see Figure 6.4).

Figure 6.4: *Trends of the Proportion of Tuberculosis/Human Immunodeficiency Virus Co-Infection Case Notifications and Antiretroviral Treatment Coverage, 2005-2012*
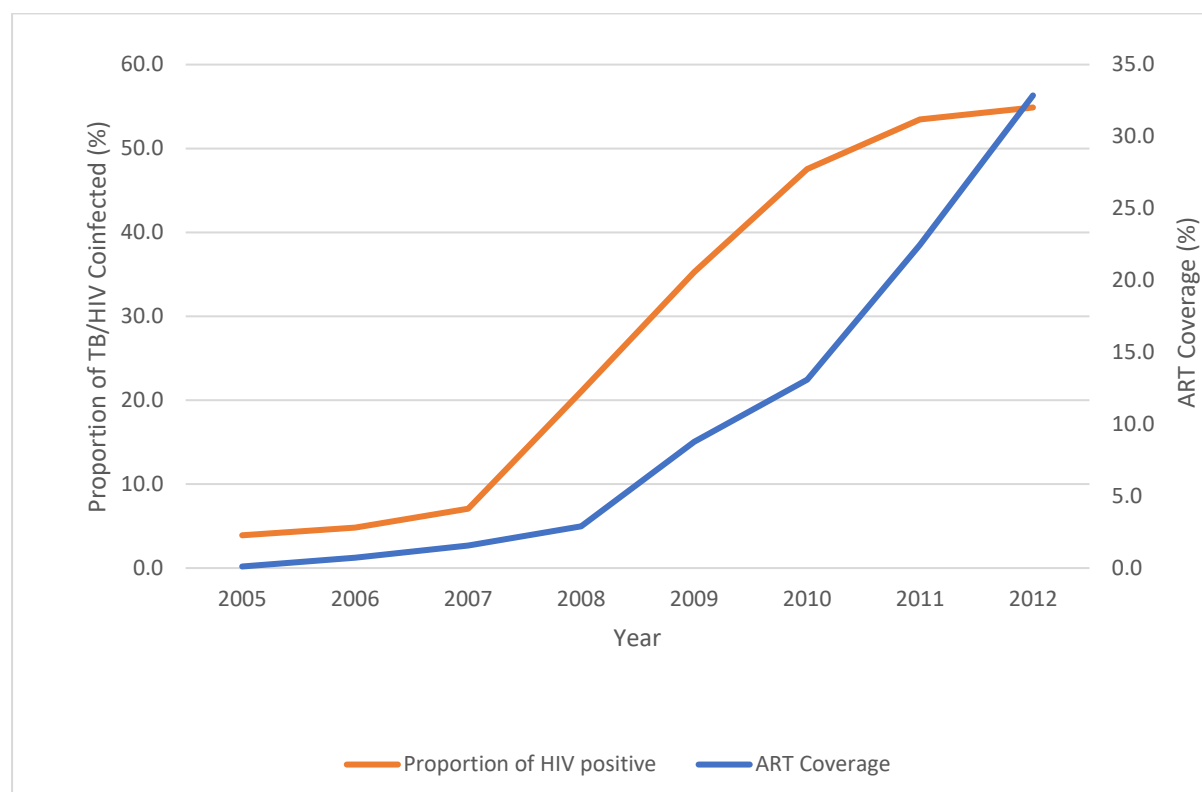
6.5 Summary

This chapter has presented the results of TB case notification rates, TB/HIV co-infection case notification rates, and TB death rates and ART coverage analysis by plotting graphs. Results showed a decrease in the TB case notification rates and TB death rates that may be attributed to ART uptake. These findings confirm the hypothesis that high ART uptake will have reduced TB related mortality. Findings in this chapter are important for the Department of Health, and those involved in developing TB and HIV/ART policy guidelines, in that they show that ART uptake can play an important role in the reduction of TB case notifications and deaths. The next chapter presents the results of the TB and HIV/ART policy guidelines review.

Chapter Seven - Results: The Review of the Tuberculosis and the Human Immunodeficiency Virus/Antiretroviral Treatment Policy Guidelines

7.0 Introduction

This chapter outlines the findings of the review of the South African TB and HIV/ART policy guidelines for the period 2004-2016 using the AGREE II tool. The hypothesis for this review was: South Africa's TB and HIV/ART policy guidelines are of poor quality. The chapter begins by presenting the results of the search strategy (see Figure 7.1). Next, the results for each domain, the overall guideline assessment, and results of the extracted recommendations for data management, monitoring, and evaluation are presented. The chapter concludes with a summary.

7.1 Results of the search strategy

Figure 7.1: *Search Strategy Flow Chart*
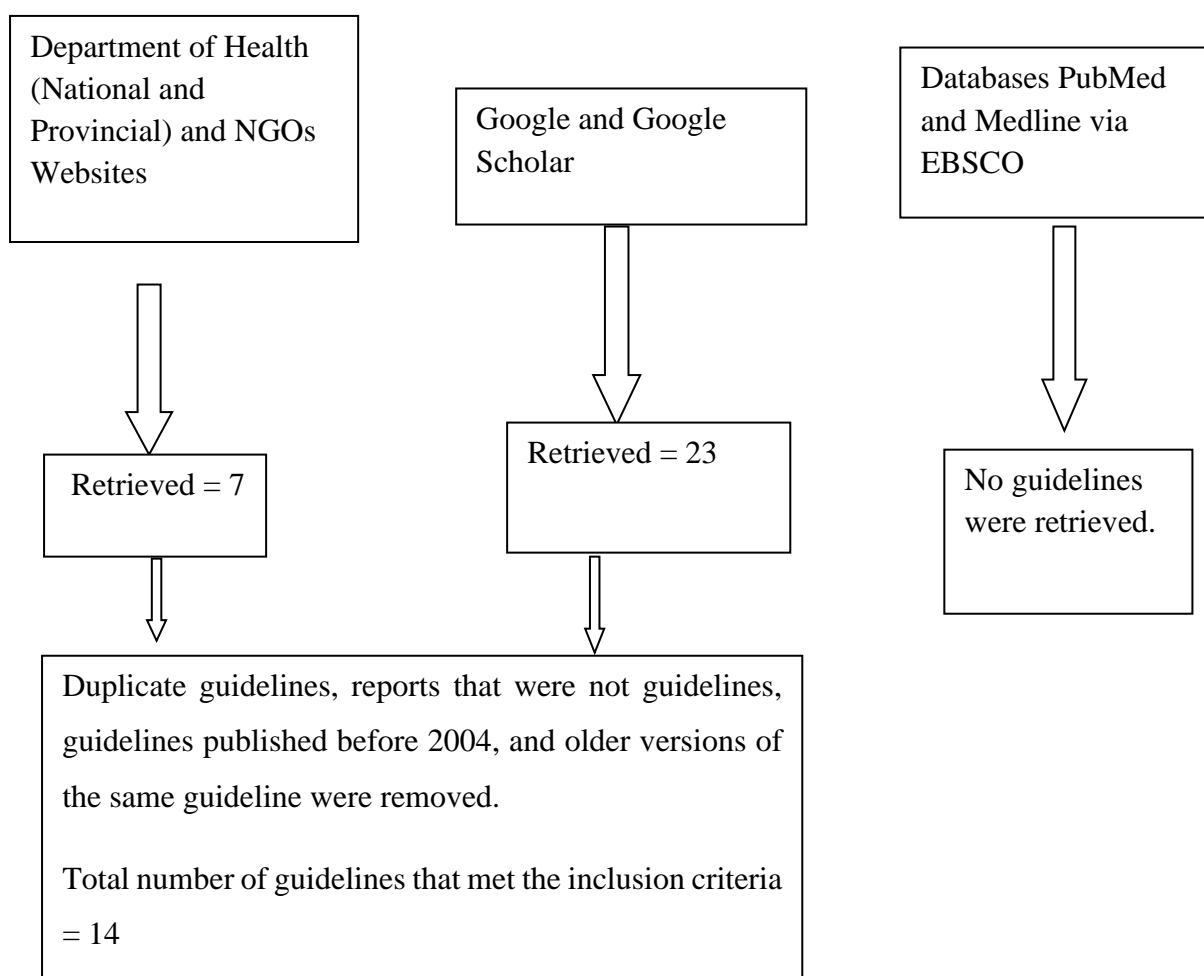
In addition to the above search strategy, 19 NGOs that had been identified during the search were contacted to provide their TB and HIV/ART policy guidelines because these could not be identified on their websites. Of those contacted, four did not have any policy guidelines and another four used TB and HIV/ARV policy guidelines for the South African National Department of Health. The remaining 12 NGOs did not respond to the request and subsequent reminders. The researcher proceeded to review the available TB and HIV/ART policy guidelines that met the inclusion criteria. Table 7.1 shows the characteristics of the 14 TB and HIV/ART policy guidelines that met the study inclusion criteria.

7.2 Results of the domain scores

Table 7.2 shows the domain scores for all 14 policy guidelines. Findings for each one of the seven domain scores are presented below.

7.2.1 Scope and purpose

None of the 14 policy guidelines had a score of more than or equal to 70% for this domain. The median score was 44.4% with a range of 0.0-66.7%. The National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015) had the highest score for this domain (66.7%) followed by the Managing HIV, A Clinician's Tool (2015) guideline with a score of 55.6%. The lowest score of 0.0% was for the Managing TB in a New Era of Diagnostics Guidelines followed by the South African Antiretroviral Treatment Guidelines (2010) with a score of (28.0%) as shown in Table 7.2.

7.2.2 Stakeholder involvement

Table 7.2 shows that of all 14 policy guidelines, none scored more than or equal to 70% for this domain. The median score was 33.3% with a range of 0.0-66.7%. The National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015) had the highest score for this domain (66.7%); followed by the Guidelines for the Management of Tuberculosis in Children (2013) with a score of 50.0%. The South African Antiretroviral Treatment Guidelines (2013) and the South African Antiretroviral Treatment Guidelines (2010) both had the lowest score of 0.0% for this domain.

Table 7.1: *Characteristics of the Retrieved Tuberculosis and Human Immunodeficiency Virus/Antiretroviral Treatment Policy Guidelines for South Africa, 2004-2016*

Guideline	Year	Publishing organisation
The South African National Tuberculosis Control Programme Practical Guidelines	2004	National Department of Health
National Antiretroviral Treatment Guidelines	2004	National Department of Health
National Tuberculosis Control Management Guidelines	2009	National Department of Health
National Tuberculosis Management Guidelines	2014	National Department of Health
The South African Antiretroviral Treatment Guidelines	2013	National Department of Health
The South African Antiretroviral Treatment Guidelines	2010	National Department of Health
Guidelines for the Management of Tuberculosis in Children	2013	National Department of Health
The South African Antiretroviral Treatment Guidelines, PMTCT guidelines	2013	National Department of Health
National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults	2015	National Department of Health
The Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults	2015	Provincial Government of Western Cape - Department of Health
Guidelines for the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional Facilities	2013	National Department of Health
Managing TB in a New Era of Diagnostics	2016	Non-Government Organisation
Managing HIV, A Clinician's Tool	2015	Non-Government Organisation
Guidelines for the Management of HIV in Children	2010	National Department of Health

7.2.3 Rigour of development

As shown in Table 7.2 none of the 14 policy guidelines had a score of more than or equal to 70 % for this domain. The median score was 8.3% with a range of 2.1-16.7%. The National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015) and the Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child

Transmission of HIV (PMTCT), Children, Adolescents and Adults (2015) both had the highest score (16.7%) for this domain. These were followed by the Managing TB in a New Era of Diagnostics (2015) guidelines with a score of 14.6%. The South African Antiretroviral Treatment Guidelines (2013) had the lowest score for this domain (2.1%); followed by a score of 6.3% for both the National Tuberculosis Control Management Guidelines (2009) and the National Tuberculosis Management Guidelines (2014).

7.2.4 Clarity of presentation

Thirteen policy guidelines had a score of more than 70%. The median score for this domain was 83.6% with a range of 66.7-94.4%. The highest score of 94.4% was by the National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015), followed by six guidelines that scored 88.9% each; the National Antiretroviral Treatment Guidelines (2004), the South African Antiretroviral Treatment Guidelines (2013), the South African Antiretroviral Treatment Guidelines, PMTCT guidelines (2013), the Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults (2015), Guidelines for the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional facilities (2013), and the Guidelines for the Management of HIV in Children (2010). The lowest score of 66.7% was for the Managing HIV, A Clinician's Tool (2015) as shown in Table 7.2.

7.2.5 Applicability

All 14 policy guidelines scored less than 70% in this domain. The median score was 19.5% with a range of 0.0-51.2%. Table 7.2 shows that the highest score of 51.2% was for both the South African National Tuberculosis Control Programme Practical Guidelines (2004) and the National Tuberculosis Control Management Guidelines (2009). These two guidelines were followed by a score of 37.5% for the Guidelines for the Management of Tuberculosis in Children (2013). Six of the guidelines had the lowest score of 0.0% each; the South African Antiretroviral Treatment Guidelines (2013), the South African Antiretroviral Treatment Guidelines (2010), the South African Antiretroviral Treatment Guidelines, PMTCT guidelines (2013), the Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults (2015), Managing HIV, A Clinician's Tool (2015) and the Guidelines for the Management of HIV in Children

(2010). The second lowest score (18.2%) was for the National Antiretroviral Treatment Guidelines (2004).

7.2.6 Editorial independence

As shown in Table 7.2, none of the policy guidelines scored more than or equal to 70% for this domain. The median score was 0.0% with a range of 0.0-25.0%. The highest score of 25.0% was for four guidelines; the National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015), Guidelines for the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional Facilities (2013), the Managing TB in a New Era of Diagnostics (2016) and the Managing HIV, A Clinician's Tool (2015). These were followed by the National Tuberculosis Control Management Guidelines (2009) with a score of 16.7%. Nine guidelines had the lowest score of 0.0% each; the South African National Tuberculosis Control Programme Practical Guidelines (2004), the National Antiretroviral Treatment Guidelines (2004), the National Tuberculosis Management Guidelines (2014), the South African Antiretroviral Treatment Guidelines (2013), the South African Antiretroviral Treatment Guidelines (2010), Guidelines for the Management of Tuberculosis in Children (2013), the South African Antiretroviral Treatment Guidelines, PMTCT guidelines (2013), the Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults (2015) and the Guidelines for the Management of HIV in Children (2010).

7.2.7 Overall guideline assessment

All the policy guidelines reviewed for this study were scored as not recommended for use for the overall guideline assessment. This finding confirms the study hypothesis that South Africa's TB and HIV/ART policy guidelines are of poor quality. The highest overall score was 'four' for the National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015). The lowest overall score of 'two' was by two guidelines; the South African Antiretroviral Treatment Guidelines (2013) and the South African Antiretroviral Treatment Guidelines, PMTCT guidelines (2013) (see Table 7.2).

Table 7.2: *Results of the Score of each Domain for each Tuberculosis or Human Immunodeficiency Virus/Antiretroviral Treatment Policy Guideline by the AGREE II Tool*

Title of the guideline	DI Score Scope and Purpose (%)	D2 Score Stakeholder Involvement (%)	D3 Score Rigour of development (%)	D4 Score Clarity of presentation (%)	D5 Score Applicability (%)	D6 Score Editorial Independence (%)	Overall guideline Assessment	Recommendation for use
The South African National Tuberculosis Control Programme Practical Guidelines 2004	38.9	44.4	6.3	77.8	51.2	0.0	3	Not recommended
National Antiretroviral Treatment Guidelines 2004	39.0	33.0	12.5	88.9	18.2	0.0	3	Not recommended
National Tuberculosis Control Management Guidelines 2009	44.4	33.3	6.3	77.8	51.2	16.7	3	Not recommended
National Tuberculosis Management Guidelines 2014	44.4	33.3	6.3	77.8	29.2	0.0	3	Not recommended
The South African Antiretroviral Treatment Guidelines 2013	50.0	0.0	2.1	88.9	0.0	0.0	2	Not recommended
The South African Antiretroviral Treatment Guidelines 2010	28.0	0.0	4.2	83.3	0.0	0.0	2	Not recommended
Guidelines for the Management of Tuberculosis in Children 2013	44.4	50.0	8.3	83.3	37.5	0.0	3	Not recommended
The South African Antiretroviral Treatment Guidelines 2013, PMTCT guidelines.	50.0	0.0	4.2	88.9	0.0	0.0	2	Not recommended

Title of the guideline	DI Score Scope and Purpose (%)	D2 Score Stakeholder Involvement (%)	D3 Score Rigour of development (%)	D4 Score Clarity of presentation (%)	D5 Score Applicability (%)	D6 Score Editorial Independence (%)	Overall guideline Assessment	Recommendation for use
National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults 2015	66.7	66.7	16.7	94.4	20.8	25.0	4	Not recommended
The Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults 2015	31.3	22.2	16.7	88.9	0.0	0.0	3	Not recommended
Guidelines for the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional Facilities 2013	44.4	44.4	10.4	88.9	29.2	25.0	3	Not recommended
Managing TB in a New Era of Diagnostics 2016	0.0	33.3	14.6	77.8	29.2	25.0	3	Not recommended
Managing HIV, A Clinician's Tool 2015	55.6	33.3	8.3	66.7	0.0	25.0	3	Not recommended
Guidelines for the Management of HIV in Children 2010	39.0	33.0	8.3	88.9	0.0	0.0	3	Not recommended

7.3 Data management, monitoring, and evaluation recommendations

This research extracted only data management, monitoring, and evaluation recommendations from the policy guidelines because it is an epidemiological study that aimed to establish what is recommended in terms of data management for the TB and HIV/ART programmes in South Africa. Although recommendations for data management, monitoring, and evaluation were not specifically labelled as recommendations, there were statements in the section of monitoring and evaluation of the guidelines that were intended to provide guidance for data management, monitoring, and evaluation of the policy guidelines. These are the ones that were extracted for this research. Table 7.3 shows the extracted data management, monitoring, and evaluation recommendations for the 14 policy guidelines.

Out of the 14 policy guidelines that were reviewed for this study, seven did not have recommendations for data management, monitoring, and evaluation that were identified. These guidelines were: the National Antiretroviral Treatment Guidelines (2004), the South African Antiretroviral Treatment Guidelines (2013), the South African Antiretroviral Treatment Guidelines (2010), The South African Antiretroviral Treatment Guidelines, PMTCT guidelines (2013), the Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults (2015), Managing HIV, A Clinician's Tool (2015), and the Guidelines for the Management of HIV in Children (2010). The seven guidelines that had data management recommendations extracted are: The South African National Tuberculosis Control Programme Practical Guidelines (2004), National Tuberculosis Control Management Guidelines (2009), National Tuberculosis Management Guidelines (2014), and Guidelines for the Management of Tuberculosis in Children (2013). Then the National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults (2015), Guidelines for the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional Facilities (2013) and Managing TB in a New Era of Diagnostics (2016).

The main recommendations identified were that standardised forms were to be utilised for data collection, data needs to be collated and analysed at a facility level, and that sub districts, districts, provinces, and the National Department of Health should run checks to validate the data. Some of the guidelines also recommended a frequency for the data analysis; for example, weekly, monthly, and quarterly. Another recommendation identified was that accurate recording at different levels is important.

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Considering these recommendations, and the high percentage of variables that had missing records that were expected to be captured, it may be argued that these recommendations are not followed during TB data management processes. Furthermore, because of these missing records, it may further be argued that the quality of these guidelines has an effect on the quality of the TB data; particularly because in some policy guidelines there were no data management recommendations.

7.4 Summary

This chapter has presented results of the AGREE II tool for the review of the South African TB and HIV/ART policy guidelines for the period 2004-2016. To the best of the researcher's knowledge, this is the first South African study to review TB and HIV/ART policy guidelines using the AGREE II tool. The results showed that for all the reviewed TB and HIV/ART policy guidelines, the 'Clarity of presentation' domain had the highest scores. None of the reviewed guidelines could be recommended for use, implying that they need to be improved. Results for the extracted recommendations for data management, monitoring, and evaluation revealed that seven of the 14 TB and HIV/ART policy guidelines did not have any recommendations that could be associated with data management, monitoring, and evaluation. Those TB and HIV/ART policy guidelines that had recommendations extracted for data management, monitoring, and evaluation revealed that they recommended accurate data recording, data collation, and analysis by the different levels of the health system (health facility, sub district, district municipality, province, and national). Information in this chapter is important for the Department of Health, for those involved in developing TB and HIV/ART policy guidelines, and those responsible for TB and HIV/ART data management, monitoring, and evaluation in South Africa. The next chapter will present the discussion for the results of this study.

Chapter Eight - Discussion

8.0 Introduction

The previous chapter presented results of the AGREE II tool for the review of the South African TB and HIV/ART policy guidelines for the period 2004-2016. In the following sections, the researcher will begin by discussing the evaluation of the TB surveillance system, followed by the epidemiological and inferential analysis of the ETR and the TB mortality. Furthermore, the geospatial analysis will be discussed followed by the concordance of ART and TB. Finally, results of the AGREE II tool for the review of the South African TB and HIV/ART policy guidelines will be discussed.

This research used national TB data including both TB cases (2005-2012) and TB deaths (2005-2015). In addition, TB cases from the ETR for 2013 to 2015 were available for Western Cape province, and were analysed. The study showed that both the ETR and the mortality TB data had 343, 872 and 391 duplicate records, respectively. Duplicate records may lead to an overestimation of TB notifications or TB deaths; therefore, for this analysis, they were removed. It can also be argued that duplicate records are an indication that TB data are not analysed at all levels of the TB surveillance system as recommended by the policy guidelines.

8.1 Evaluation of the TB surveillance system

The quality of data generated by a surveillance system is important because it provides a complete picture of the health issue that is under surveillance (CDC, 2001); in addition to guiding its acceptability by those who operate in it (CDC, 2001; Mlotshwa et al., 2017). The study revealed that variables in the ETR for date of birth, HIV status, and for those that reported to be HIV positive and were on ART had low levels of completeness 5.1-62.1%, 20.6-90.6%, and 0.01-19.7% respectively. Although the levels of completeness were different, similar findings for those with low completeness were shown to be for date of birth and ART by a study done at a district level in the Western Cape Province of South Africa (Mlotshwa et al., 2017). There was a similar finding for low completeness for HIV status for a study that was conducted for TB data evaluation involving three provinces in South Africa (Podewils et al., 2015). Furthermore, the study showed a number of key variables; gender, age in years, province, district municipality, sub district, started on treatment and treatment outcome, with levels of completeness that were 100% for the study period. There were similar findings of 100% level of completeness for age and gender in New Zealand (The Institute of Environmental Science and Research Ltd, 2018) and the contrary for HIV status and ART.

Furthermore, this study investigated the timeliness of the TB surveillance in Western Cape province. To the best of the researcher's knowledge, this is the first study to investigate timeliness of the TB surveillance system in Western Cape province. The findings for this study revealed a very low percentage of TB cases were initiated on treatment within 48 hours of collecting a specimen. In addition, there was a high percentage of TB cases that had an unknown timeliness because there was no date for when the specimen was taken. These findings have implications for the TB programme because delayed TB diagnosis and treatment may be associated with an increase in morbidity and mortality of the affected persons, as well as an increase in transmission of the TB infection in the community (J. Golub, E et al., 2006; Greenaway et al., 2002; Zahar et al., 2001). Unlike studies that were conducted in Canada (Gershon, Wobeser, & Tu, 2008), the UK (Saldana et al., 2013), Spain (Cruz-Ferro et al., 2014), and Zimbabwe (Takarinda et al., 2015), this study could not establish why there was a delay in initiating treatment. Furthermore, the findings related to the unknown amount of time taken to initiate TB cases on treatment may be related to the data quality of the TB surveillance system; for example, dates for specimen collection that are not captured in the system. This finding is important because both early diagnosis and TB treatment prevent further disease progression (Takarinda et al., 2015). The South African National Department of health set a target from the time of specimen collection to treatment initiation to be within 48 hours (Department of Health, 2014) but these results indicate that South Africa is still falling behind on this target. Furthermore, currently case detection rate and successful treatment are 69% and 77% respectively (WHO, 2019).

As a way of computing the concordance, the study performed a comparison between the total number of TB deaths in the ETR and those in the civil registration system, which revealed that the total number of TB deaths for the study period were lower year on year in the ETR than in the civil registration system. In fact, a total of 391 136 (61.6%) TB deaths were in the civil registration system and not recorded in the ETR. These are very important findings which may indicate the impact on following up of TB cases and again on the data quality of the TB surveillance system. If a TB death is not recorded in the ETR, it may indicate that the surveillance system never identified it. However, a more accurate estimate of the reliability of the TB surveillance system in capturing TB deaths would be obtained if records between the two data bases were matched.

8.2 Epidemiological and inferential analysis of the ETR data

Findings of the epidemiological analysis of the study during the period 2005-2012, were that the South African national TB notification rate increased; however, it was not statistically significant. Furthermore, the findings showed a significant number of males diagnosed with TB than females; in fact, there was a male:female ratio of TB cases of 1.2:1—similar to the global trend of 1.7:1 (WHO, 2016a). The findings of more males being diagnosed with TB than females were similar to global findings by the WHO (2018a) in its annual global TB report. In addition, these findings are similar to other studies that were conducted for example in Japan (Hagiya et al., 2018) and a systematic review and meta-analysis study (Horton, MacPherson, Houben, White, & Corbett, 2016). There were also similar findings for studies conducted in China (L. Wang et al., 2014), Haiti (Charles et al., 2017), the UK (C. M. Smith et al., 2017), and Kenya (Nyamogoba & Mbuthia, 2018).

Males having higher TB notification rates than females could be due to financial barriers that females may face; thus hindering them from seeking for health care and resulting in not being offered the opportunity of being diagnosed with TB (Long et al., 1999; Weiss et al., 2006). Furthermore, gender roles can also have a negative impact on females seeking health care with associated stigma (Nair, George, & Chacko, 1997; Oshi, Oshi, Alobu, & Ukwaja, 2016). This study could not ascertain as to why males have higher TB notification rates than females because it only used TB notification data. However, a systematic review and meta-analysis study by Horton and colleagues (2016) revealed that men are disadvantaged in seeking and/or accessing TB services in a number of settings. There is also evidence that, overall, men are not well served by health services (Lim et al., 2012; H. Wang et al., 2012) and they usually delay seeking health care (van den Hof, Najlis, Bloss, & Straetemans, 2010).

The study further showed that the highest TB notification rates were in the 35-44 and 25-34 age groups for males and females, respectively. These gender specific TB notification rates are important as overall TB notification rates tend to mask those ages that have the highest TB notification rates. The study further showed that females in the 15-24 and 25-34 age groups had higher TB notification rates than males in the same age groups. These findings are similar to a study conducted in Pakistan (Codlin et al., 2011) and similar to TB notification rates in some European countries in the previous century (Holmes, Hausler, & Nunn, 1998). However, the situation in European countries has since changed to males having higher TB notification rates than females in those age groups. For the Pakistan study, the researchers were unable to conclude as to the causes of high TB notification rates in females, but suggested it could be

due to sociocultural factors and the nutritional status of young women (Codlin et al., 2011). Although the current study could not establish the reasons as to why females in these age groups had higher TB notification rates, this is an extremely important finding in terms of guiding the focus of interventions for TB control.

This study revealed that there were increases in both pulmonary TB and extra pulmonary TB, although in both cases, the increases were not statistically significant. However, any increase in pulmonary TB is of public health importance because pulmonary TB cases are infectious. For example, if left untreated, one pulmonary TB case is capable of infecting on average between 10 and 15 people each year (Blumberg, 2005). Unlike pulmonary TB, extra pulmonary TB is less infectious but can cause health discomfort and may not easily be diagnosed by health professions (S. Lawn, D. & Zumla, 2012; Vadwai et al., 2011). Both these findings are important for health professions in that TB cases, especially pulmonary TB, once diagnosed, should commence treatment early to reduce the chances of others being infected. Although there are no definitive symptoms of TB, health professions should suspect extra pulmonary TB for those people that may present with signs and symptoms that are unclear.

Another important finding is that by 2012, more than half (54.9%) of all TB cases were co-infected with HIV. Following efforts by the WHO to integrate HIV and TB services, the South African Department of Health set up an HIV/TB unit in 2004 to coordinate the activities of the TB and HIV programmes (Loveday & Zweigenthal, 2011). This is evidenced in the data where the proportion of TB cases that tested positive for HIV increased steadily from 2005. Contrary to the findings of this study, a cross-sectional study of 49 randomly selected health facilities in South Africa found that less than half of the newly registered TB patients in 2011 were diagnosed as being HIV co-infected (Chehab, Vilakazi-Nhlapo, Vranken, Peters, & Klausner, 2013). However, the WHO, in 2010, reported that more than half (60%) of the tested TB cases, in South Africa were HIV co-infected (WHO, 2011). These findings are important for health professions to strengthen the integration of TB and HIV services, and ensure that TB patients are tested for HIV—since one in every two TB patients is likely to be HIV infected. Moreover, HIV is a well known risk factor for TB (Gough & Kaufman, 2011; Harries & Zachariah, 2008), making it an essential component in the management of TB.

The study also revealed a low proportion of TB cases that were reported cured for the study period. Some studies in England, Wales and Northern Ireland (Ditah et al., 2008), Ethiopia (Wondale et al., 2017), and Pakistan (Atif et al., 2018), and New Zealand (The Institute of

Environmental Science and Research Ltd, 2018) have reported higher proportions of cured TB cases. This very low proportion of cured TB cases could be as a result of almost a third of the TB cases having not been evaluated; in fact, in 2011, 76% of the TB cases were not evaluated (no treatment outcome was assigned). In addition, almost a quarter (24.7%) of the TB cases, for the study period, completed treatment but without bacteriological confirmation of cure. This finding is critical if South Africa is to meet its targets for successful treatment; more so, because even the proportion of TB cases that successfully completed treatment were just over half of (53.6%) the notified TB cases. Therefore, efforts should be intensified to make sure that TB cases are evaluated after treatment is completed and, in addition, to investigate the underlying causes of the non-evaluation of TB cases. Furthermore, those TB cases that complete treatment should also be bacteriologically confirmed as having been cured of TB.

Tuberculosis relapse cases are of public health concern and may be applied as a measurement of how effective the TB control programme is, because TB relapse cases might indicate that the TB treatment was not completed or there is an HIV infection (Mirsaeidi & Sadikot, 2018) which was not diagnosed by the TB programme. This study showed that there was a statistically significant decline in the proportion of relapse TB cases over the study period; however, an important finding is that the proportion of TB relapse cases was high in the 35-44 and 25-34 age groups. This finding is similar to national studies conducted in the USA (Kim et al., 2016) and Uzbekistan (Gadoev et al., 2017). This study could not investigate further why these age groups were the ones that were mostly affected by relapse TB but it has been suggested that poor adherence to treatment and smoking (J, de Fátima Pessoa Militão de Albuquerque, de Alencar Ximenes, & Rodrigues, 2008), as well as alcohol consumption, could be the underlying causes (Gadoev et al., 2017). As previously discussed, it may be argued that these findings confirm that smoking (Bates, 2007; Maurya et al., 2002) and alcohol (Lönnroth et al., 2008) are risk factors for TB. The implications of this finding are that TB control efforts should be focused towards these age groups.

The study performed further analysis to lower geographical levels of South Africa. This was important because an overall analysis masks what may be the level of TB notification rates in those geographical levels (provinces, district municipalities, and sub districts or the local municipalities). For the period of study, further findings included a variation in the cumulative annual TB notification rates for the provinces, district municipalities, and sub districts/local municipalities. These findings of TB notification variation rates by geographic regions are in line with other studies (Davidow, Marmor, & Alcabes, 1997; Hamusse, Demissie, & Lindtjørn,

2014; Ormerod, Charlett, Gilham, Darbyshire, & Watson, 1998). The study further revealed that KwaZulu-Natal and North West provinces had the highest cumulative annual TB notification rates, which were in fact higher than the overall cumulative annual TB notification rate for South Africa. Because the study used data from the ETR, it could not establish the causes of the high TB notification rate in KwaZulu-Natal province. However, it may be related to the fact that the province also has the highest number of HIV positive people in South Africa (Bärnighausen et al., 2008) and HIV is a known risk factor for TB (Bucher et al., 1999; Corbett et al., 2003; Sonnenberg et al., 2001). Furthermore, for North West province, because mining is a risk factor for TB (Kleinschmidt & Churchyard, 1997; J. Murray et al., 2011), and there are many mines in that province, this maybe the reason for the high TB notification rates. In addition, as discussed earlier, mining is also considered a risk factor for HIV (Williams et al., 2015) and, in turn, HIV is a known risk factor TB. At the district level, the study further showed that, Dr Kenneth Kaunda district municipality, in North West province, had the highest cumulative annual TB notification rate which could be due to the location of this district, which is peri urban (likely limited access to TB services) with a number of gold and uranium mines (Lebina et al., 2015). Mining is linked to a high prevalence of HIV. These findings are particularly important in informing the TB control programme about the need to address the high notification rates in these provinces and district municipalities.

Findings of Western Cape province are important because they underpin the importance of studies at lower levels because analysis at a national level has potential to obscure trends in the lower levels. A finding of a statistically significant decline of the cumulative annual TB notification rate in Western Cape Province is an important one. This finding provides an opportunity for the other South African provinces to learn from the TB control activities of Western Cape province.

8.3 Epidemiological and inferential analysis of the TB mortality data

Tuberculosis mortality data may provide an overview of the health status of a population; therefore, its quality for instance completeness is important. This study revealed that most of the variables had a level of completeness of 100% with only two variables—smoking status and level of education of the deceased—having low levels of completeness. This is an important finding for guiding the efforts of improving civil and vital registration. Efforts should be directed towards improving the level of completeness of these two variables. Moreover, smoking is a risk factor for TB (Bates, 2007; Maurya et al., 2002); therefore, its level of

completeness is important to enable further research in order to contribute knowledge to its role as a risk factor.

The study showed a statistically significant decline in the rate of TB deaths over the study period. These findings were similar to the global trend (WHO, 2018a) and for studies in countries like Japan (Hagiya et al., 2018), the USA (Barnes et al., 2011), and the UK (P. Glaziou, Floyd, & Raviglione, 2018). This downward trend is an important finding, especially for the SDGs and the End TB strategy—both of which call for a reduction in TB deaths. The study further revealed that for the period 2005-2015, there was a higher cumulative annual TB death rate in males than in females. This finding is similar to other studies in other countries (Hagiya et al., 2018; Kyu et al., 2018; Llorca, Dierssen-Sotos, Arbaizar, & Gómez-Acebo, 2012). Although this study could not independently establish why there were more TB male than female deaths, it may be due to risk factors associated with TB that are more prevalent in men; for example, smoking (R. E. Watkins & Plant, 2006) and co-morbidities like HIV (Hagiya et al., 2018). Another important finding is that for the study period, for both males and females, the cumulative annual TB death rate was highest in the 35-44 age group. In fact, this same age group had the highest cumulative annual TB notification rate for males whereas for females it was the 25-34 age group. While a similar study in South Africa had the same finding (Kootbodien et al., 2018), this finding is in contrast to the findings of a study in Japan where TB deaths were higher in the older age groups believed to be due to increased exposure of the elderly to other chronic health conditions (Hagiya et al., 2018). Tuberculosis deaths in the 35-44 age group in South Africa has implications in that this is the age group that is economically active; therefore, it is important that health workers in the TB control programme pay particular attention to this age group in order to reduce the number of TB deaths.

Illiteracy has been associated with TB mortality (Gomes et al., 2015), especially through an association of education and SES (Winkleby, Jatulis, Frank, & Fortmann, 1992); indeed, SES is a known risk factor for TB. However, this study showed that the highest proportion of TB deaths was in those with Grade 12 (secondary education). This finding should be interpreted with caution because almost half of the TB deaths had an unspecified level of education.

The type of occupation has been established as a risk factor for TB (Kleinschmidt & Churchyard, 1997; J. Murray et al., 2011; Rosenman & Hall, 1996). This study found variations in the proportion of TB deaths in occupation groups and industry of occupation. There were a high proportion of TB deaths in those people in armed forces; unspecified occupations, not

elsewhere classified; not economically active persons; and elementary occupations, for instance cleaners and labourers. These findings are similar to those of a study conducted in South Africa (Kootbodien et al., 2018) and could be because these are occupations of a lower socioeconomic level. People who were not economically active, are exposed to poverty, and lack access to health care services (Hargreaves et al., 2011). Further findings of a high proportion of TB deaths in those people working in industries categorised as private households, exterritorial organisations, representatives of foreign governments, and other activities not adequately defined, are of major importance for the South African TB control programme. Moreover, some of those TB deaths are for people that are not permanent residents of South Africa (exterritorial organisations and representatives of foreign governments); therefore, they might have been infected outside South Africa and pose a potential risk to spread TB infection.

Contrary to those studies that have established an association between smoking and risk for TB (Bates, 2007; Houtmeyers et al., 1999; H. Lin et al., 2007; Maurya et al., 2002), this study showed that TB death rates were higher in non smokers. Moreover, a study conducted in South Africa showed that smoking increased the odds of dying from TB (Kootbodien et al., 2018). Therefore, it may be argued that the reason for this finding by the current study could be related to the level of completeness of the smoking variable. In fact, almost a half of the TB deaths had smoking status as unspecified; therefore, these results should be interpreted with caution.

Furthermore, this study showed that for the period 2005-2015, the majority of TB deaths (64.3%) had occurred in a hospital and had been ascertained by either a post-mortem (31.5%) or an opinion of the attending medical practitioner (25.0%). These findings have implications for the utility of the TB mortality data for the TB control programme in South Africa because over 10% of TB deaths had unspecified method of ascertainment and another over 10% with place or institution of death unspecified. In addition, the findings may indicate the level of accessibility to health care in South Africa. Deaths that are professionally ascertained have the potential to improve the accuracy with which TB deaths are confirmed. This reduces the number of deaths in general that would be registered with ill-defined causes of death that potentially include those that may be TB deaths. Overall, deaths with ill defined cause of death, especially those that occur outside health facilities without a medical profession, may limit the use of that data for public health policy and epidemiological research (Polprasert et al., 2010). Therefore, the ascertainment of TB death and place of death may play an important role towards the reliability and quality of the TB mortality data. These findings are important for

the TB control programme and the South African health department in that there is a need to improve on the proportion of TB deaths that occur in hospitals and are ascertained by the medical profession.

The study further established variations in TB death rates among population groups, provinces, district municipalities, and sub districts or local municipalities. The black African population, KwaZulu-Natal province, and Ugu district municipality (located in KwaZulu-Natal province), had the highest cumulative annual TB death rates for the study period. Another South African study showed similar findings of high TB deaths in KwaZulu-Natal province (Kootbodien et al., 2018). Furthermore, many parts of KwaZulu-Natal province, including Ugu district municipality, are rural with the majority of inhabitants being black Africans. According to Mayosi and colleagues, a large proportion of South Africans live in poverty with limited access to, for instance, reasonable housing conditions (Mayosi & Benatar, 2014). Therefore, high TB death rates in the black African population, KwaZulu-Natal province, and Ugu district municipality may be related to low SES. Moreover, it is known that there is an association between TB and SES (Lönnroth et al., 2009; Muniyandi et al., 2007; Waaler, 2002), and that the poor may be unable to access health care services (Ataguba et al., 2011). These findings are important, especially the finding for the high cumulative annual TB death rate of 312 per 100 000 population in Ugu district municipality despite it being the district municipality that had neither the highest TB notification rate nor the highest proportion of TB deaths for the period of study. This means that health care workers in KwaZulu-Natal province should direct TB prevention efforts towards Ugu district municipality.

8.4   Geospatial analysis

To the best of the researcher's knowledge, this is the first nationwide and district municipal level TB geospatial analysis that has investigated both TB notifications and deaths in South Africa. The results for the geospatial analysis have shown the added benefits of analysing TB data, with particular emphasis on space and time, rather than depending only on analysis of routinely collected surveillance data that computes TB prevalence and incidence without the time and space component. To improve prevention and control strategies of TB, it is important to investigate if there is a relationship between location and occurrence of TB. Therefore, to understand these dynamics, it may be argued that integrating surveillance data with geospatial analysis may provide valuable input for any planned targeted TB prevention interventions. This study confirms the utility of the GIS to demonstrate any presence of areas with high risk of TB; and as an effective tool for monitoring, especially in those areas with high TB and HIV

rates and low SES (Moonan et al., 2004; Tiwari, Adhikari, Tewari, & Kandpal, 2006). Furthermore, the information produced by the geospatial analysis can be very useful in informing and preparing TB programme officials to develop TB prevention programmes that are effective and relevant for a specific district municipality. The effectiveness of the GIS in directing public health action has been demonstrated in studies in other fields (Aronson, Wallis, O'Campo, & Schafer, 2007; M. Choi, Afzal, & Sattler, 2006; McLafferty & Grady, 2005).

This PhD research identified district municipalities that had low levels of completeness for date of birth for the ETR data and smoking status for the deceased for the TB mortality data. Incomplete data has implications both at a TB programme level and for research. At a TB programme level, incomplete data may mean that TB cases may not be identified and followed up in addition to underestimating the burden of TB. Incomplete data may also hinder research because the variables of interest for a particular research may be incomplete. This research could not conclude if there was an association between incomplete data and occurrence of TB hot spots because not all the district municipalities that had high percentages of incomplete date of birth or smoking status were TB hot spots.

The study also revealed that in 2005, Dr Kenneth Kaunda district municipality in North West province had the highest overall unadjusted TB notification rate, as well as in male and female; whereas in 2010, it was Ugu district municipality in KwaZulu-Natal province that recorded the highest rate. Similarly, for the age sex standardised TB notification rates, Dr Kenneth Kaunda district municipality had the highest overall, male, and female age sex standardised TB notification rates in 2005; however, in 2010 it was uMkhanyakude district municipality in KwaZulu-Natal province that had the highest overall and male age sex standardised TB notification rates. Similar to 2005, Ugu district municipality in KwaZulu-Natal province had the highest male TB standardised notification rate. As earlier discussed, the occurrence of these high TB notification rates may be attributed to the location of Dr Kenneth Kaunda district municipality which is in a mining area for gold and uranium (Lebina et al., 2015); and mining is a known risk factor for TB (Kleinschmidt & Churchyard, 1997; J. Murray et al., 2011). As discussed earlier, HIV is a risk factor for TB. Therefore, the current rapid spread of HIV has resulted in high TB notification rates. In South Africa, HIV has been fuelled by the system of migrant labour, especially on the gold mines, which has resulted in breakdown of family life and an increase in extra-marital relationships, mostly with migrant sex workers from neighbouring countries (Williams et al., 2015). Similarly the high HIV prevalence in KwaZulu-Natal province (Bärnighausen et al., 2008), where both Ugu and uMkhanyakude district

municipalities are located, may be attributed to the high TB notification rates. The spatial lag regression analysis performed in this study further confirmed an association between TB, HIV and SAMPI. In addition to a high HIV prevalence in Ugu and uMkhanyakude district municipalities, this study has demonstrated that the high level of SAMPI in these district municipalities is associated with high TB notification rates.

This study further investigated unadjusted and standardised TB death rates in 2005 and 2010. The differences that were observed between unadjusted and age sex standardised TB notification and death rates showed the importance of removing those effects that may arise as a result of a variation in the age composition of the population under study. Overcoming the confounding impact of the different age structures of the population groups in South Africa is important because the provinces have different population compositions; for instance, in Western Cape province there are more Coloured or White people than in Gauteng province and, therefore, their age composition is different (Statistics South Africa, 2019). For instance, there are many more elderly people in the White population group than amongst Coloured people. The results revealed that in 2005, the unadjusted TB death rates were highest in Cacadu district municipality in Eastern Cape province for the overall, male, and female rates. However, in 2010 the unadjusted TB death rates were highest in Xhariep district municipality in Free State province for both the overall and female. The results further revealed that Ugu district municipality had the highest unadjusted TB death rates for male in 2010. For the standardised TB death rates, the study found that uMzinyathi district municipality in KwaZulu-Natal province had the highest death rates overall, for male, and female. The high rates of TB deaths that were observed in the three provinces—Eastern Cape, Free State, and KwaZulu-Natal— may be linked to the low SES of their inhabitants. SES and poverty are known risk factors for TB (Lönnroth et al., 2009; Muniyandi et al., 2007; Waaler, 2002). These are important findings which further indicate that some district municipalities in KwaZulu-Natal province had the highest TB notification rates in addition to high TB death rates.

Furthermore, the study revealed that these same district municipalities in KwaZulu-Natal province had high levels of SAMPI for both 2001 and 2011. The dimensions of SAMPI are health, education, standard of living, and economic activity (Statistics South Africa, 2014). Levels of SAMPI are inversely related to health, education, standard of living, and economic activity; for instance, a high level of SAMPI equates to poor health, lack of education, poor standard of living, and unemployment which leads to low or no income. Therefore, these findings confirm that TB is associated with lack of education, poor standard of living, and

income, and has also been identified by other studies (Gehlen et al., 2019; Wubuli et al., 2015). These spatially dependent relationships between TB and its risk factors; for example socio economic risk factors as identified by the integration of SAMPI in this study, can guide provinces, district municipalities in developing comprehensive TB prevention and control strategies taking into consideration these socio economic risk factors. In order to be effective, these strategies will require an intersectoral approach. The results of this study are similar to those conducted in other developing countries; for instance, Brazil (Gehlen et al., 2019; Lima et al., 2019) and Zimbabwe (Chirenda et al., 2020). The comparison between other developing countries is appropriate because, for example, Brazil has a number of similarities with South Africa in terms of the level of inequality (Assouad, Chancel, & Morgan, 2018).

Furthermore, the study revealed that all the Global Moran's I values for 2005 and 2010 for the overall, male, and female unadjusted and age sex standardised TB notification and death rates were greater than zero, and all the Z-values were positive and significant except for the 2005 overall age sex standardised TB notification rate that was not significant. This meant that there was spatial autocorrelation in the TB notification and death data for both 2005 and 2010. In addition, these findings indicated that there was a higher level of similarity in the unadjusted and standardised TB notification and death rates between a district municipality and those district municipalities located next to it for both 2005 and 2010. The findings of this study are consistent with other studies of spatial epidemiology of TB in other developing countries which have shown significant spatial autocorrelation (Harling & Castro, 2014; Liu et al., 2011; T. Wang, Xue, Chen, Ma, & Liu, 2012). The findings further revealed that both the Global Moran's I and Z values for 2010 were higher than those of 2005. These high values mean that there was a high level of similarity between those district municipalities that were located next to each other and a higher intensity of clustering for the TB notification and death rates of 2010 than those of 2005.

Furthermore, the study performed a rates box map analysis to establish the spatial distribution of TB notification and death rates. For both 2005 and 2010, the research revealed that the overall, male, and female TB notification and death rates were higher on the eastern side of the country mainly in KwaZulu-Natal province. As discussed earlier, the spatial regression analysis confirmed that there is a positive association between HIV and SAMPI and this study has identified KwaZulu-Natal province as the one with a high HIV prevalence and a high level of SAMPI. These findings are particularly important for health workers in this province to intensify TB control and prevention strategies with a focus on strengthening collaborations

with the HIV programme and other Government departments (i.e., education, social development, and labour).

The results of both the Local Moran and the Local G identified heterogeneity in the TB data. The study revealed that in 2005, there were clusters (hot spots) for overall, male, and female for the crude and age sex standardised TB notification and death rates on the north western part; while in 2010, these clusters shifted mostly to the eastern region of South Africa. In addition, the Local G was able to identify local clusters of dependence where the Moran's I was unable to do so. This study revealed spatial dynamics of TB which has shown a distinct district municipality trend of hot spots occurring in areas that mostly have high levels of SAMPI and HIV. These findings are similar to other studies (Kolifarhood, Khorasani-Zavareh, Salarilak, Shoghli, & Khosravi, 2015; Wubuli et al., 2015) that have demonstrated that populations in certain areas all share common TB risk factors; for instance, low SES. These studies were conducted in developing countries like South Africa. The first, in Iran (Kolifarhood et al., 2015), identified TB clusters in the older, poorer regions that were located on the periphery; while Wubuli et al.'s (2015) study, conducted in China, identified an association between the gross domestic product (GDP) of the area and the clusters of TB. This current study further identified some district municipalities that were spatial outliers (high-low) which means that a district municipality with high TB rates is surrounded by a cluster of low TB rates. The study also identified some low-high spatial outliers (a district municipality with low TB rates is surrounded by a cluster of high TB rates). These findings are similar to three TB studies conducted in other developing countries—China (Rao et al., 2016) and Brazil (Gehlen et al., 2019; Lima et al., 2019). These studies are specially cited because, as previously mentioned, Brazil has similarities with South Africa. Additionally, South Africa shares similarities with China in terms of ensuring equity, the burden of TB, and addressing the social determinants of health (Marten et al., 2014). The identification of these spatial outliers provides an opportunity for future research to investigate the factors that could be associated with the occurrence of observed differences in TB rates in neighbouring district municipalities.

The study further conducted a spatial lag regression analysis. The results of the spatial lag regression analysis revealed that TB notification and death rates were higher in hot spot district municipalities that had higher HIV prevalence and lower SES (high level of SAMPI). This study confirmed what has long been established—that there is a positive association between HIV (Corbett et al., 2003; Kwan & Ernst, 2011; Narasimhan et al., 2013; Padmapriyadarsini,

Narendran, & Swaminathan, 2011), SES (Hargreaves et al., 2011; Lönnroth et al., 2009; Muniyandi et al., 2007; Odone et al., 2014; Waaler, 2002), and TB. These spatial lag analysis results should be considered by the Department of Health when developing TB control interventions if these interventions are to be effective. In addition, these findings further underscore the importance of implementing or strengthening a multi-faceted approach involving stakeholders outside the health sector in order to control TB in the identified district municipalities.

8.5 Concordance between ARV treatment and TB

The researcher identified one study that investigated ART and incidence of TB (Nanoo et al., 2015) in South Africa; however, the researcher did not identify any literature or published papers for South Africa that compared ART uptake with TB/HIV co-infection case notification rates and TB death rates from either the mortality TB data or the ETR data. Therefore, this makes this study the first one to investigate these comparisons in South Africa.

In addition to being the first study to investigate both these indicators, it is an important study relevant for South Africa because the TB epidemic in South Africa is fuelled by HIV. As mentioned earlier, South Africa has the largest number of HIV-associated TB cases (Churchyard et al., 2014). It has been argued that ART reduces the risk of TB in people living with HIV (Kanyerere et al., 2014; Suthar et al., 2012). As previously discussed, at the end of 2003, South Africa commenced a free national ART programme (Karim et al., 2009). Although TB patients were not prioritised for ART uptake until 2009, it could be argued that this may have contributed to the persistently high TB mortality rates (Karim et al., 2009). Anti retroviral treatment aims at reducing the patient's viral load to a level where it cannot be detectable and ensures that it remains undetectable, in addition to improving the immunological status with the cluster of differentiation 4 (CD4) count rising and remaining above the baseline of between 500 and 1 400 cells per cubic millimetre of blood. The CD4 cells help the body to fight infection; yet, HIV targets these cells, compromising the immune system of affected individuals. The ART is potent because it reduces the plasma viral load (HIV-RNA) with a resultant increase in the CD4 cell count which improves the immune system (Mermin et al., 2011; Rajasekaran et al., 2009). With an improved immunological status, the patient may be able to fight off opportunistic infections resulting in a decrease in HIV-related morbidity and mortality. Since 1999, South Africa has scaled up ART coverage which could be argued has provided an opportunity for a reduction in TB case notification rates, TB/HIV notification rates, and TB deaths. Studies done in Malawi and Swaziland revealed that an increased uptake of

ART was associated with a marked decline in TB case notifications (Haumba et al., 2015; Kanyerere et al., 2016; Kanyerere et al., 2014). South Africa, like many other African countries, has progressively increased the prescribed CD4 cell count threshold for eligibility of starting ART over a period of 10 years, from greater than 200 cells/mm^3 in 2004 (Department of Health, 2004) to the current threshold of greater or equal to 500 cells/mm^3 (Department of Health, 2015). It may be further argued that an increase in the prescribed CD4 threshold affords more people living with HIV an opportunity to start on ART when the HIV infection is still in its initial stages, which could further reduce their risk of developing TB (Takarinda, Harries, Sandy, Mutasa-Apollo, & Zishiri, 2016).

This study revealed that from 2009, when TB patients were prioritised for ART, there was a decrease in TB notification rates, although the proportion of TB deaths (from the TB mortality data) and the proportion of TB deaths from the ETR started decreasing in 2008. Findings for the decrease in TB notification rates may be associated with the scaling up of ART coverage, as was identified in a South African study (Nanoo et al., 2015) and studies conducted in other countries within Southern Africa; for instance, Malawi, Swaziland, and Zimbabwe (Haumba et al., 2015; Kanyerere et al., 2016; Kanyerere et al., 2014; Takarinda et al., 2016); as well as in high income countries (The HIV-CAUSAL Collaboration, 2012). Contrary to these findings, a study in South Africa (not at a national level) found that people living with HIV with a CD4 cell count of more than 700 cells/mm^3 still had higher incidence rates of TB cases than among those people who were HIV negative in the community (Gupta, Wood, Kaplan, Bekker, & Lawn, 2012).

8.6 Review of the TB and HIV/ART policy guidelines

To the best of the researcher's knowledge, this is the first review of TB and HIV/ART guidelines for South Africa using the AGREE II tool. This research aimed to assess the quality of TB and HIV/ART policy guidelines in South Africa for the period 2004-2016 using the AGREE II tool. In addition, the research aimed to identify recommendations for data management, monitoring, and evaluation within the policy guidelines under study. In this section, the researcher will first discuss the findings of the review of the TB and HIV/ART policy guidelines using the AGREE II tool and, thereafter, discuss the recommendations for data management, monitoring and evaluation that were extracted.

The majority of policy guidelines for this study were developed by the South African Government—one was developed by the Provincial Government of Western Cape and 11 by

the National Department of Health. Two policy guidelines were developed by an NGO. None of the policy guidelines reviewed for this study could be recommended for use meaning that they require improvement. The review revealed that the quality of the most recent policy guidelines was not overall better than the older ones; this finding is similar to that of the study for the appraisal of policy guidelines for smoking cessation in people with severe mental illness (Sharma et al., 2017), although in contrast with another study (Polus et al., 2012).

This study revealed that the 'Clarity of presentation' domain for the reviewed policy guidelines consistently had high scores, followed by the 'Scope and purpose' domain. These findings were in contrast with other studies that found the 'Scope and purpose' domain scoring higher than the 'Clarity of presentation' domain (Polus et al., 2012; Sabharwal et al., 2013; Sharma et al., 2017; Xie et al., 2016). For a guideline to have a high score for the 'Scope and purpose' domain, the AGREE II tool requires that the overall objective, health question, and target populations be specifically described. Although, for this study, the majority of the reviewed TB and HIV/ART policy guidelines specifically described the overall objective and the target populations, they did not specifically describe the health question which led to lower scores.

The study further revealed that the scores for the 'stakeholder involvement' domain were low; in fact, three of the policy guidelines scored 0.0%. These findings are similar to those of another study that found low scores in this domain (Yao et al., 2017). This domain requires involvement of various professionals that have content expertise in different disciplines (e.g., methodologists and clinicians). It also suggests that there should be input from patients and the public with a clear description of the target users (AGREE Next Steps Consortium, 2017). This study revealed that none of the policy guidelines evidenced having involved any patients or the public during the policy guideline development, this was similar to findings of another study (Yao et al., 2017). It may be argued that involvement of various stakeholders would improve the quality of the guidelines. These findings have implications on uptake of the services—if the consumers of the services (TB and HIV affected individuals) are involved in the development of the policy guidelines this may improve the quality and uptake of the TB and HIV services and lead to new or improved sources of information (Crawford et al., 2002).

Furthermore, the study found that the reviewed TB and HIV/ART policy guidelines for the period 2004-2016 had low scores for the 'Rigour of development' domain; these results are similar to other studies done within South Africa and Southern Africa (Kredo et al., 2012; Wiseman et al., 2014). Low scores for this domain were mainly because all the guidelines did

not show that systematic methods (i.e., search strategy for literature, search terms, and databases) were used to search for evidence; again, similar to findings from other studies (Sharma et al., 2017; Yao et al., 2017). In addition, none of the policy guidelines reported any criteria for including or excluding evidence that was identified. Furthermore, none of the reviewed policy guidelines reported that they had been externally reviewed by experts prior to their publication. If the reviewed policy guidelines for this study had been externally reviewed, as prescribed by the AGREE II tool, this would have positively impacted their quality. These findings indicate that policy guideline developers should focus on literature search and evidence the process of gathering the literature while developing policy guidelines, in that way the scores for this domain could be improved.

All the policy guidelines, apart from one, scored above 70% in the 'Clarity of presentation' domain. The study found that these high scores were mainly as a result of policy guidelines being able to provide recommendations that were specific and unambiguous, especially for those that were related to the treatment of TB and HIV. The policy guidelines also reported and clearly presented different options for the management and diagnosis of TB and HIV. In the majority of policy guidelines, the key recommendations could be easily identified. These findings are similar to those of other studies that used the AGREE II tool in other fields (Beckett et al., 2019; Boluyt, Lincke, & Offringa, 2005; De Haas, De Vijlder, Van Reesema, Van Everdingen, & Neumann, 2007; Harpole et al., 2003; Hurdowar et al., 2007). High scores for this domain are important because they reflect on how well TB and HIV patients can be managed, which is a critical component in the prevention and control of these two health conditions.

Regarding the 'Applicability' domain, the study revealed that this had very low scores for the policy guidelines that were reviewed. According to the AGREE II tool, the criteria for the Applicability' domain includes describing facilitators and barriers to the application of the policy guideline, considering potential resource implications for the implementation of the recommendations, as well as providing tools on how the recommendations can be implemented (AGREE Next Steps Consortium, 2017). For this study, the low scores were attributed to the fact that all policy guidelines did not report on the facilitators and barriers to their implementation. Furthermore, all policy guidelines did not report on the potential resource (human or financial) implications associated with the application of the recommendations. Facilitators, barriers, and potential resources have an impact on the successful implementation of policy guidelines; therefore, it is important that policy guidelines report on them. The two

policy guidelines that had the highest score (51.2%) for this domain were the South African National Tuberculosis Control Programme Practical Guidelines (2004) and the National Tuberculosis Control Management Guidelines (2009). These two policy guidelines had the highest score mainly because they included tools for data collection as well as a list of indicators to be monitored, as stipulated by the AGREE II tool. Findings of low scores for this domain were similar to findings from other studies in other fields (Boluyt et al., 2005; De Haas et al., 2007; Harpole et al., 2003; Hurdowar et al., 2007).

The findings of this study for the 'Editorial independence' domain were that this was the domain with the lowest scores by the majority of the TB and HIV/ART policy guidelines that were reviewed. For this domain, the AGREE II tool requires an explicit statement that the views or interests of whoever funded the development of the policy guidelines have had no influence on the final recommendations, and for the policy guideline developers to declare whether they have any potential conflict of interest (AGREE Next Steps Consortium, 2017). The main reason for the very low scores for this domain were that the reviewed South African TB and HIV/ART policy guidelines for 2004-2016 did not report on the source of funding or a funding body; neither did they record nor address the competing interests of the policy guideline development group members. These findings were similar to those of other studies (Quintyne & Kavanagh, 2019; Sharma et al., 2017).

Regarding the findings for the overall assessment of the reviewed policy guidelines, the study revealed that none of the South African TB and HIV/ART policy guidelines for the period 2004-2016 could be recommended for use. This judgement was based on the results of the domains and the items for each of the policy guidelines. The main reasons for not recommending any of the policy guidelines for use were because the reviewed policy guidelines did not specifically describe the health question, and none of the policy guidelines showed evidence of having involved any patients or the public during policy guideline development. Furthermore, all the policy guidelines failed to show that systematic methods (i.e., search strategy for literature, search terms, and databases) were used to search for evidence, and none of the policy guidelines reported any criteria for including or excluding evidence that was identified. In addition, none of the policy guidelines reported on the facilitators and barriers to their implementation, neither did they report on the potential resource implications. Lastly, all the guidelines omitted reporting on the source of funding or a funding body; neither did they record nor address the competing interests of the policy guideline development group members. These findings warrant that, during policy guideline

development, these items should be addressed in order to produce good quality policy guidelines that may be recommended for use. These findings are similar to one study which reviewed the South African policy guidelines for the cessation of smoking, using the AGREE II tool, and did not get recommended for use (Quintyne & Kavanagh, 2019).

8.7 Policy guideline recommendations for data management, monitoring, and evaluation

The AGREE II tool requires that recommendations are presented in flow charts, boxes, tables, and bold fonts (AGREE Next Steps Consortium, 2017). The reviewed TB and HIV/ART policy guidelines for this study did not clearly present recommendations for data management, monitoring, and evaluation in the prescribed AGREE II format. This made the identification of recommendations within the TB and HIV/ART policy guidelines difficult. The way recommendations are presented may have a major impact on the success of the implementation of the policy guidelines, especially if they are not clear. Seven of the 14 reviewed South African TB and HIV/ART policy guidelines for the period 2004-2016 did not have any data management, monitoring, and evaluation recommendations that could be extracted for this study. Our of the seven TB and HIV/ART policy guidelines that had data management, monitoring, and evaluation recommendations, only one was an HIV/ART policy guideline. However, these seven TB and HIV/ART policy guidelines that had data management, monitoring, and evaluation recommendations that could be extracted were consistent with the type of recommendations that were made. All policy guidelines recommended data collation and analysis, as well as the use of standardised forms for monitoring TB and HIV programmes. This is an important finding because multiple reporting forms may have a negative impact on data quality. Six of the seven TB and HIV/ART policy reviewed guidelines specifically recommended that data should be analysed at the health facility level; however, only the Guidelines for the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional Facilities (2013) did not specifically recommend data analysis at the health facility level. Four of the TB and HIV/ART policy guidelines specifically recommended that data analysis should be conducted at all levels (health facility, sub district, district, province, and national). Furthermore, five of the seven TB and HIV/ART policy guidelines recommended that data be complete and accurately recorded. Two of the policy guidelines—Managing TB in a New Era of Diagnostics (2016) and National Tuberculosis Management Guidelines (2004)—further recommended that data should be analysed on a monthly and quarterly basis; while the third policy guideline—Guidelines for

the Management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional Facilities (2013)—recommended that TB registers must be reviewed weekly for completeness and correctness. A comparison with the ETR data that had incomplete records indicated that these recommendations are not adhered to. Such recommendations are important for the production of good quality TB or HIV/ART data by the TB or HIV/ART national programmes. Good quality TB data is important for the monitoring of the performance of the National TB programme (Melese et al., 2018) in order to identify any areas of the TB programme that may need improvement.

8.8 Limitations

The ETR data had some limitations, especially as regards to the completeness of the data. Some variables (e.g., date of birth, HIV status, and those on ART), had low levels of completeness. In addition, the data did not have certain variables that could be useful in making certain conclusions; for instance, it lacked variables like occupation and smoking status. The ETR data for the whole country was for the period 2005-2012, making it difficult to make a comprehensive comparison with the mortality TB data which covered the period 2005-2015.

Similar to the ETR data, the mortality TB data also had limitations due to completeness. Variables for smoking and level of education of the deceased had the lowest levels of completeness.

This study used secondary TB data for the ETR and the civil registration system for geospatial analysis. As mentioned, these TB data sources may have missing TB cases or deaths. Despite this limitation, the study added new knowledge by investigating spatial TB notifications and deaths at a district municipal level—a level at which primary health care services like TB services are offered in South Africa. In addition, this study was able to identify hot spots and relate them to SES and HIV.

The observed decline of TB case notification rates, TB/HIV co-infection case notification rates, and TB death rates for this study could not be entirely associated with ART uptake because this is a retrospective quantitative study. However, the observed decline may be attributed to ART uptake for the reason that ART improves the immunological status of the affected individual by raising their CD4 count.

As previously mentioned, the numerators for the study (e.g., TB case notifications and ART uptake) might not be accurate. TB notifications may be affected by the sensitivity of smear

microscopy which may lead to under or over diagnosis of TB cases; furthermore, there may be issues due to data quality as a result of the way data is captured in the ETR. As regards to smear microscopy, South Africa has now moved to using the GeneXpert technology for diagnosis. The introduction of the GeneXpert is likely to increase the accuracy of detection of those TB cases that could otherwise have been missed.

Another potential limitation for this study is that the AGREE II tool does not specifically guide on the scoring criteria that distinguishes between a high and low quality policy guideline. This is entirely left to the reviewer's discretion. For this study, the researcher trained on the AGREE II tool so that he could objectively grade the policy guidelines and be guided by previous studies. A second limitation for the review of the policy guidelines is that the study may have missed some TB and HIV/ART policy guidelines that were developed by the NGOs, as a result of NGOs not responding to the requests from the researcher. A third possible limitation for the review of policy guidelines is that because the majority of the TB and HIV/ART guidelines that were reviewed for this study were developed by South African Government Departments (the National Department of Health and the Western Cape Department of Health), the research is not able to explicitly comment on those guidelines that were developed by other sectors in South Africa.

8.9 Summary

This chapter presented the discussion of the findings of this study. The chapter highlighted reasons as to why some groups are vulnerable to high TB notifications and deaths. The chapter confirmed the association between TB, HIV, and SAMPI. Furthermore, the concordance between ART and TB was discussed. The results of the AGREE II were also discussed. Lastly, the study limitations were considered. The next chapter will present the conclusion and recommendations.

Chapter Nine - Conclusion and Recommendations

9.0 Introduction

The previous chapter presented the discussion for this research. An overview of the epidemiology of TB in South Africa for the period 2005-2015 was presented in Chapter One. Literature for the epidemiology of TB was presented in Chapter Two. The methods for this study were detailed in Chapter Three. The study findings were reported and discussed in Chapters Four (Evaluation of the TB surveillance system and the epidemiological analysis), Five (Geospatial analysis), Six (Concordance between ART and TB), and Seven (Review of the TB and HIV/ART policy guidelines). Chapter Eight offered a discussion of the findings. This final chapter presents the conclusion and recommendations of the study.

9.1 Study overview

This study is a quantitative dominant mixed methods one. The study performed secondary data analysis on two TB data sets in South Africa. Furthermore, the study analysed TB and HIV/ART policy guidelines using the AGREE II tool. The research question was: How well does the TB surveillance system perform in South Africa, and what is the impact on the reported epidemiology of TB?

To answer this question, an evaluation of the TB surveillance system using the updated CDC guidelines and an epidemiological analysis were conducted. In addition, geospatial analysis was undertaken and, finally, the South African TB and HIV/ART policy guidelines for 2004-2016 were analysed. This thesis is the first study to have combined surveillance and policy document analysis. Findings from the epidemiological and geospatial analyses have contributed to new epidemiological knowledge; including, the identification of those at risk populations (host) and their location (place) in terms of high TB notification and death rates for the period 2005-2015 (time) at a district municipal level in South Africa. The main finding of interest from the analysis of South African TB and HIV/ART policy guidelines from 2004-2016 was that none of the reviewed guidelines could be recommended for use; therefore, requiring improvement.

In the next section the researcher will present three theoretical issues that came up during the writing of this thesis. These are: the need to address the inequality in TB infections and deaths; the importance of analysing and addressing TB infections and deaths focusing on a district

municipal level; and the need for intergovernmental agencies to work together to fight TB in South Africa.

9.2 Theoretical issues identified in the thesis

The first theoretical issue identified is the need to address the inequality in TB infections. As evidenced in the epidemiological and geospatial analyses of this thesis, some age groups and district municipalities were at a higher risk of TB infection or death than others. Therefore, for this thesis, inequalities refer to the differences in TB disease burden and mortality that exist among a particular population group and district municipalities. It has been suggested that it is critical that health inequalities are reduced in light of the fact that they affect certain groups of people (Mackenbach, 2012; Preda & Voigt, 2015) and can be prevented (Graham, 2004; Woodward & Kawachi, 2000). It has been further argued that for a government that is interested in improving the health of its people, it should consider the health impact of alternative options during the formulation of policies, because health inequities can be managed by the introduction and implementation of relevant policies (Preda & Voigt, 2015; Woodward & Kawachi, 2000) such as equity focused policies. Through the use of SAMPI, this thesis has demonstrated what has long been established—that there is a relationship between TB and SES. These findings are similar to those of studies in Brazil (de Castro, Sadahiro, Pinto, de Albuquerque, & Braga, 2018; Harling & Castro, 2014) where it has been established that populations with low incomes generally report more illnesses and are likely to die earlier. The consequences of low income are that the affected people will not have appropriate housing, good food, and access to education; all of which impact the health of the affected individuals. It has been argued that in order to tackle health inequalities in a society, redistributive public health and social policies should be implemented through social infrastructures; for instance, affordable housing, welfare support, and availability of employment. For this to be effective in a country like South Africa, the government should aggressively address issues of poor housing (especially for those people living in informal settlements), corruption, and high unemployment rates. Individuals living in informal settlements are at a higher risk of disease due to lack of access to clean water, overcrowding, and inadequate sanitation. Unemployment usually leads to poverty which eventually causes stress or may lead to poor health behaviours (e.g., smoking) which are known risk factors for TB. Thus, one way of tackling TB infections or deaths in South Africa is to aggressively come up with job creation initiatives so that people gain employment, thereby reducing the unemployment rate.

The second theoretical issue identified is whether it is important to analyse and address TB infections and deaths focusing on a district municipal level in South Africa. This thesis has demonstrated the importance of analysing TB data at a lower level than a national or even a provincial level in South Africa. The thesis has identified that there is a variation in the distribution of TB disease and deaths throughout the country, with some district municipalities being at higher risk than others. Therefore, depending on only the national level analysis will usually mask what is happening further down, beyond the provincial level in South Africa. This masking may mean that those populations most vulnerable will not be identified and, therefore, will not be targeted for TB interventions. Targeting of specific people and district municipalities with focused interventions will help South Africa's TB programme managers to assess the effectiveness of the implementation of TB interventions. This calls for the national Department of Health to lead the development of national and district municipality specific TB policies. Furthermore, the Department of Health should intensify efforts to gather and analyse data at a district municipal level and support district municipalities in improving the quality and use of their TB data for public health action.

The third theoretical issue is the need for intergovernmental agencies to work together to fight TB in South Africa. As mentioned earlier, this thesis has identified an already established link between TB infections and deaths with the SES of those affected. Thus, poverty and lack of education are risk factors for TB. It may be argued that because these risk factors fall outside the mandate of the Department of Health, on its own, the Department of Health will not be able to successfully tackle TB infections and deaths. The evidence also underlines the necessity for intersectoral health action as it is only through action in all government portfolio areas that inequities will be addressed. Therefore, Government departments at a local level should work together with the local Department of Health towards interventions that tackle TB. This means that departments like local government, education, social development, housing, and labour should intensify the activities of the TB working group with the aim of pooling and directing resources towards TB interventions at a district municipal level. In addition, NGOs should also participate in this collaboration.

9.3 Summary of key findings

The following sub sections provide a summary of the key findings from this study.

9.3.1 Evaluation of the TB surveillance system

The study revealed that completeness of TB data was low for the variables of date of birth, HIV status, and ART; whereas gender, age in years, province, district municipality, sub district, started on treatment, and treatment outcome had 100% completeness. Completeness was also low for level of education and smoking status of the deceased for the TB death data. The TB surveillance system in Western Cape province had poor timeliness for initiation of treatment after specimen collection. For the concordance, a total of 391 136 (61.6%) TB deaths were in the civil registration system but not recorded in the ETR which means that the ETR identified approximately 39% of the TB deaths. These findings are critical to the TB programme because TB data that are not complete can potentially introduce bias that may result in resources being misdirected from where they are needed most. This may lead to poor health outcomes (Harron, Wade, Muller-Pebody, Goldstein, & Gilbert, 2012; Lalor et al., 2018). Similar to this study, a study conducted in England and Wales revealed that TB deaths that were recorded in the TB surveillance system did not tally with those of the vital registration system (Lalor et al., 2018). These findings underscore the importance of improved data capturing, collation, and analysis at all levels of the TB surveillance system.

9.3.2 Epidemiological analysis

An important finding from this study is that for the period 2005-2012, TB notification rates increased with a significant number of males diagnosed with TB. Furthermore, high TB notification rates were found in the 35-44 and 25-34 age groups for males and females, respectively. Tuberculosis in these age groups is of major concern because these are the age groups that are mostly economically active. If they are not productive due to TB, they might not be able to continue with employment which will lead to a loss of income and subsequent implications for their families.

Another important finding is that by 2012, more than half (54.9%) of all TB cases, were co-infected with HIV. This finding underscores the importance of strengthening programmes and policies in South Africa that have been developed over time to target TB and HIV co-infected people. The study also revealed that KwaZulu-Natal and North West provinces, and Dr Kenneth Kaunda district municipality, had the highest TB notification rates for the study period. The TB notification rate in Western Cape province was both on a decline and statistically significant. These results demonstrated that certain groups of people are more vulnerable to TB; therefore, they require interventions and policy guidelines specific to them. Furthermore, other provinces in South Africa need to work closely with Western Cape province

to learn from their TB programme and understand how they managed to reverse the trend of the increasing TB notification rates.

The study further showed a statistically significant decline in the rate of TB deaths over the study period, with higher cumulative annual TB death rates in males than females. Furthermore, the highest death rates were in the 35-44 age group for both men and women. The black African population, KwaZulu-Natal province, and Ugu district municipality, had the highest cumulative annual TB death rates for the study period. Again, this finding has revealed what is already established—that TB deaths are high in certain groups of people. This calls for the government to strengthen TB control interventions coupled with policies that target TB in these vulnerable groups. With these findings, it can be argued that this PhD has contributed to new epidemiological knowledge by identifying those at risk populations (host) and their location (place) in terms of high TB notification and death rates for the period 2005-2015 (time) in South Africa.

9.3.3 Geospatial analysis

In order to effectively control and prevent TB, the TB programme needs to have information on where the TB cases and deaths are and the extent of the TB burden. Geospatial analysis can provide this information and identify those areas that are at risk of TB disease. However, this information should be of good quality. This study revealed a presence of spatial autocorrelation because all the Global Moran's I values for 2005 and 2010 for TB notification and death rates were greater than zero and all the Z-values were positive and statistically significant apart from the one for 2005 (overall age sex standardised TB notification rates). The study further identified presence of heterogeneity with clusters (hot spots) shifting from the western in 2005 to the eastern part of South Africa in 2010. The identification of these clusters underscores the importance of understanding TB transmission dynamics at a district municipal level and developing TB prevention interventions specific to district municipalities. This requires recognition of the local context in the efforts to prevent and control a disease (e.g., TB) with inclusion of a neighbourhood approach (Hipp & Chalise, 2015); for instance, the district municipalities that are located next to each other. These findings are important for the Department of Health because they have been able to identify district municipalities that may be prioritised for TB interventions by directing more resources to those district municipalities.

Furthermore, the study revealed that those areas with a high level of SAMPI and HIV were more likely to be a hot spot. These results have shown that using GIS provides additional

important information on the socio-economic risk factors of TB transmission (in the case of this study, SAMPI) (Mathema et al., 2017). Mostly the available evidence of geospatial epidemiology of TB has always described the TB burden in terms of prevalence over a period of time or incidence. The use of GIS analysis (e.g., the Global and Local Moran's I, the Local G indices plus the spatial regression analysis) has further provided information on how TB transmission may occur (Moonan et al., 2004; Shaweno et al., 2018); for instance, the presence of spatial autocorrelation, heterogeneity, and dependency. As previously argued, this information is important in identifying areas that require targeted TB interventions which may include data validation to ascertain the existence of either high TB notification or death rates or clusters (hot spots).

9.3.4 Concordance of ART and TB

The study found that as TB notifications increased there was an increase in ART coverage, which meant that those that were co-infected were being identified and had an opportunity to get ART. Furthermore, the study revealed that TB deaths decreased as ART coverage increased. This finding is important for the Department of Health, particularly because the TB burden in South Africa is driven by HIV (Churchyard et al., 2014). Therefore, the Department of Health should strengthen and continue with the integration of TB/HIV activities with the aim of reducing the burden of TB in people living with HIV in the country.

9.3.5 Review of the TB and the HIV/ART policy guidelines

As stated in Chapter Three, the quality of policy guidelines is important because policy guidelines translate policy into practice. This means that if the policy guidelines have recommendations for data management, for example, they should potentially translate into good data management practises like analysing the data at all levels of the TB surveillance system. The results showed that for the majority of all the reviewed South African TB and HIV/ART policy guidelines, the 'Clarity of presentation' domain had the highest scores while the 'Editorial independence' domain had the lowest scores. Clarity of presentation meant that these policy guidelines were clear in terms of the language used, how the policy guideline is structured, and its format. This is an important finding and the researcher may argue that if policy guidelines are clear that means users are able to understand the content thus making their implementation easier. Another important finding was the low score for the 'stakeholder involvement' domain. To obtain a high score, this domain requires involvement of various professionals as well as patients. Involving patients may increase their confidence in TB services; thus, it could be argued, further improving the uptake of TB services. Therefore, as

a way forward, the Department of Health should consider involving TB patients (or former TB patients) while developing TB and HIV/ART policy guidelines. The findings of the low scores for 'Editorial independence' are also important. For the scores to be high, it is recommended that an explicit statement that the views or interests of whoever funded the development of the policy guidelines have had no influence on the final recommendations, as well as a declaration by the policy guideline developers for any potential conflict of interest. Following this criterion affords transparency and no bias in the developed policy guidelines. The Department of Health should consider incorporating these criteria when developing future policy guidelines.

Another very important finding of this study is that none of the reviewed policy guidelines was recommended for use. As outlined in Chapter Seven, the policy guidelines lacked many of the items that would render them to be of good quality; for instance, there was no mention of systematic methods for searching the literature, no search terms, or mention of databases used to search for evidence. Furthermore, the policy guidelines did not report on the facilitators and barriers for their implementation, there was no information on the potential resource implications. The Department of Health needs to adapt these items when developing policy guidelines.

The study further revealed that seven (50%) of the 14 TB and HIV/ART policy guidelines reviewed did not have any recommendations that could be associated with data management, monitoring, and evaluation. It may be argued that lack of these recommendations may be partly associated with the poor data quality which was one of the findings of this study.

9.4 Key recommendations

The following recommendations are based on the findings of this study and are proposed to improve data quality of the South African TB surveillance system in addition to improving TB prevention. The recommendations presented focus on policy, surveillance data management, and research; and it is suggested that the National Department of Health, together with provinces and districts, should work on implementing these recommendations.

9.4.1 Policy

Develop TB and HIV/ART policy guidelines that are of good quality meeting the criteria as set out in the AGREE II tool. This may require involvement of people that specialise in policy analysis and, after developing these policy guidelines, then involve experts for an external review.

Develop TB data management policies to be used and referred to by all those involved in data management; for example, health information officers, data managers, and data capturers.

Generate a process of developing integrated plans for district municipalities that consider neighbouring district municipalities in efforts to control TB across district municipalities in the neighbourhood.

There is a need for a national strategy with clear objectives, targeted timelines, and how to prioritise resources to fight TB and poverty—particularly in those provinces and district municipalities where hot spots were identified. Because the hot spots are mainly in rural areas, the national strategy should clearly identify ways of strengthening human resources in these district municipalities.

9.4.2 Surveillance data management

It should be emphasised and regularly communicated to staff responsible for TB data management that data analysis should be done at all levels of the health system; that is, from the health facility to the National Department of Health. This may require strengthening refresher trainings in data management for those involved in TB surveillance. These trainings should use actual data from the ETR so that trainees can begin to recognise the gaps in the data.

Establish a TB data management team between Statistics South Africa and the National Department of Health to analyse, collate, reconcile, and link ETR and TB mortality data on a regular basis. This will help improve data quality, especially the completeness of the ETR and vice versa.

The study proposes including geospatial analysis as a routine to TB data management. This will enable the TB programme to identify those district municipalities that have hot spots for TB in order that planned, evidence based, targeted TB prevention interventions may be developed and implemented. Furthermore, using the geospatial analysis routinely can assist the TB programme to systematically track TB trends with a possibility of identifying where TB is going to spread next. This will assist the TB programme to prepare in advance to implement TB control interventions and, therefore, limit its impact to vulnerable communities.

9.4.3 Research

Due to the poor data quality, as identified by this study, the researcher argues that there is a need to repeat the study using the most recent TB data and a third data set, for example laboratory TB data, to compute completeness, sensitivity, and PPV of the TB surveillance

system. Furthermore, a capture-recapture method would be useful to estimate the exact prevalence of TB in South Africa.

The main method used in this PhD study was quantitative. Further research at a national level combining a qualitative method; for instance in-depth interview and focus groups among stakeholders in the TB programme, could provide more information about the performance of the South African TB surveillance system among other attributes (e.g., simplicity, flexibility, representativeness, acceptability, and stability).

The study identified spatial outliers. Further research may be needed to investigate the factors that could be associated with the occurrence of the differences in the TB notification and death rates in the neighbouring district municipalities with spatial outliers. In addition, further research may be needed to investigate why hot spots were in the western part of the country in 2005 and then shifted to the eastern part in 2010.

The study revealed that there was a very low percentage of TB cases that were initiated on treatment within 48 hours of collecting a specimen. It is suggested that South Africa should further investigate the factors that would lead to a delay in initiating treatment and possibly ways to improve this delay.

9.5 Contribution to new knowledge

This PhD has contributed new knowledge on the epidemiology of TB; for example, establishing the presence of TB hot spots for both notifications and deaths in South Africa. There is a paucity of studies of spatial TB epidemiology that cover the whole country. There have been some localised studies in South Africa that concentrated on XDR TB in KwaZulu-Natal province (Kapwata et al., 2017), TB in Eastern Cape province (Obaromi, Ndege, & Yongsong, 2019), and TB in children in a community in Western Cape province (Middelkoop, Bekker, Morrow, Zwane, & Wood, 2009). There was new knowledge about the functioning of the TB surveillance system, especially the data quality and timeliness. As the world is struggling with the COVID-19 pandemic, the importance of a functional surveillance system for an infectious disease that can identify and follow up all cases has never been more important.

The study is the first to analyse TB and HIV/ART policy guidelines (2004-2016) in South Africa using the AGREE II tool. The study identified that all the policy guidelines that were reviewed were not fit for use as they did not meet the criteria. This information is critical for

the Department of Health, for those involved in developing TB and HIV/ART policy guidelines, and those responsible for TB and HIV/ART data management, monitoring, and evaluation in South Africa to review the way policy guidelines are developed.

9.6 Conclusion

This PhD study will be very useful for the national Department of Health in their efforts to control TB in South Africa. This study has demonstrated the importance of using secondary data sources, in combination with geospatial techniques, to identify those that could be at risk and provide important information usually required to inform public health policies.

Furthermore, the findings for this research indicated a disproportionate distribution of the TB burden, which means that certain groups of people (e.g., males and those in the 35-44 age group) in South Africa, including those living in locations with a high level of SAMPI and HIV, had a higher burden of TB during the period of study. The existence of these identified inequalities in the burden of TB, underscores the importance of developing targeted public health interventions and policies directed towards the most vulnerable populations who happen to be those with observed high TB notification and death rates, and are located in district municipalities with hot spots.

This research further identified gaps in the TB surveillance data which has major implications for TB surveillance. For example, if the TB mortality data has more deaths than the TB surveillance data, as was the case for this study, there is a possibility that a number of people infected with TB were never identified by the surveillance system. Further, it may imply under reporting of TB notifications which may have ramifications in terms of continued undetected TB infections and community transmission.

Tuberculosis can be prevented and cured but it can be argued that the continued existence of poor TB data may, in part, contribute to the factors that have sustained TB as a challenge for South Africa. Addressing the identified challenges facing TB surveillance in South Africa will require engaging with vulnerable groups right from the time when policies are being developed, as suggested in the AGREE II tool attribute of stakeholder involvement, followed by directing enough resources into TB prevention activities and surveillance data management at a district municipal level. In addition, the maps generated by the GIS should be shared with vulnerable groups because they could act as a basis for designing new solutions for public health action. The PhD has further proposed recommendations in the area of policy, surveillance data management, and further research all aimed at improving TB surveillance in South Africa.

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Appendices
Appendix A: Ethics Approvals

AUTEC Secretariat

Auckland University of Technology
D-88, WU406 Level 4 WU Building City Campus
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

11 December 2017

Nick Garrett
Faculty of Health and Environmental Sciences

Dear Nick

Re Ethics Application: **17/369 The role of surveillance systems in the epidemiology of tuberculosis in South Africa**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 11 December 2020.

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation then you are responsible for obtaining it. If the research is undertaken outside New Zealand, you need to meet all locality legal and ethical obligations and requirements. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries, please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: dan.kibuuka@gmail.com; Nadia Charania; Penny Neave; Alain Vandal

HUMAN RESEARCH ETHICS COMMITTEE

22 August 2018

Mr Dan Kibuuka
Biostatistics Unit
SAMRC Pretoria

Dear Mr Kibuuka

Protocol ID:	EC006-5/2018
Protocol title:	The role of surveillance systems in the epidemiology of Tuberculosis in South Africa
Meeting date:	28 May 2018

Thank you for your application to the Committee, which was discussed at the 28 May 2018 meeting, and your response submitted on 17 August 2018. I am pleased to inform you that ethics approval is now granted for the study.

Please note that the approval is valid for 1 year, i.e. from 28 May 2018 to 27 May 2019. Any changes to the research protocol must be submitted as an amendment. Any adverse events must be reported within 48 hours. Any protocol deviations have to be reported.

Wishing you well with your research.

Yours sincerely

[signature]

Prof Danie du Toit
Chairperson: SAMRC Human Research Ethics Committee

Members present at the meeting: Prof D du Toit (Chairperson), Adv J Early, Dr H Etheredge, Prof A Kengne, Ms M Ledwaba, Prof C Lombard, Dr AG Loxton, Mr G Makanda, Dr E Nicol, Prof C Wiysonge

HUMAN RESEARCH ETHICS COMMITTEE

13 March 2020

Mr Dan Kibuuka
Biostatistics Unit
SAMRC Pretoria

Dear Mr Kibuuka

Protocol ID:	EC006-5/2018
Protocol title:	The role of surveillance systems in the epidemiology of Tuberculosis in South Africa
Meeting date:	24 February 2020

Thank you for your progress report and application to the Committee for renewal, dated 4 February 2020. The Committee noted the report and granted ethics approval for the study for another year.

Please note that the approval is valid for 1 year, i.e. from 24 February 2020 to 23 February 2021. Any changes to the research protocol must be submitted as an amendment. Any serious adverse events must be reported within 48 hours. Any protocol deviations have to be reported.

Wishing you well with your research.

Yours sincerely

Prof Danie du Toit
Chairperson: SAMRC Human Research Ethics Committee

Members present at the meeting: Prof D du Toit (Chairperson), Ms S Behardien, Adv J Early, Dr H Etheredge, Ms M Ledwaba, Prof C Lombard, Dr A Loxton, Dr E Nicol, Dr W Zembe

Appendix B: TB Patient Blue Card

SOUTH AFRICA
NATIONAL TUBERCULOSIS CONTROL PROGRAMME
PATIENT CLINIC/HOSPITAL CARD

y y y y
Registration number cccc/cccc

Transferred/ c — N = Newly registered.
Moved? — M = Moved in from facillity in this dristrict
T = Transferred in from facillity in another district

d d mm y y y y
Registration date cc/cc/cccc

Health District _____ Clinic/Hospital _____ Treatment point _____
Surename _____ Full name (s) _____
Home address _____
(First) _____
_____
Work address _____
_____
Telephone (H) _____ Telephone (W) _____
Home address _____
(New) _____
_____
Work address _____
_____
Telephone (H) _____ Telephone (W) _____

Race c — 1 = African/Black — Gender c M/F — Age cc Years
2 = Coloured — d d mm y y y y
3 = Indian/Asian — Date of birth cc/cc/cccc
4 = White
5 = Unspecified/Other

PATIENT CATEGORY
c (N) — New Patient
c (RC) — Retreatment after previous cure — c (RF) — Retreatment after failure
c (RAC) — Retreatment after previous completion — c (RI) — Retreatment after interruption

INTERNATIONAL CODE FOR DISEASE
cA16.2	TB PULMONARY	cA16.7	TB primary	cA18.8	TB other organs
cA16.3	TB lymph nodes	cA17.0	TB meningitis	cA19.9	TB miliary
cA16.5	TB pleura/other resp org	cA18.0	TB bones/joints		

NOTIFICATION INFORMATION
d d mm y y y y
Has patient been notified? cYes cNo — Date of birth cc/cc/cccc

Completed by _____ Telephone number _____

SPUTUM RESULTS

Pre - Treatment		End of intensive Phase (2/3 months)		Discharge		Culture **		
Smear Date(s)	Smear Result(s)	Smear Date(s)	Smear Result(s)	Smear Date(s)	Smear Result(s)	Specimen Date(s)	Culture Result	Suscept Results

** Non-converters and retreatment cases

REGIMEN AND DOSAGES

Treatment start date

Regimen 1 - New adult c Regimen 2 - Retreatment adult c Regimen 3 - Children c cc/cc/cccc

a. INITIAL INTENSIVE PHASE
Other drugs (specify)

Drug	RHZE	RHZ	S				Weight at Diagnosis
Number tabs							kg.

H = Isoniazid   R = Rifampicin   Z = Pyrazinamide   E = Ethambutol   S = Sreptomycin

* The use of fixed-dose combinations is a central part of national TB Programme guidelines.

Use one of the following sybols in the upper space of the appropriate box and initial in the lower space after the drugs have been administered:

a= Medication takken under supervision at clinic.

X = Patient did not collect medication.

O = Patient did not have to collect medication (e.g. weekend).

− = Medication collected for self-administration or supervision elsewhere; draw horizontal line (-) to indicate number of days supply were given.

Month	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			

b. CONTINUATION PHASE

Drug	RH	E				Weight at Diagnosis
Number tabs						kg.

Month	Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			

TREATMENT SUPERVISOR

c Relative   c Employer   c Teacher   c Community health worker   c Clinic nurse   c Other

Name ———————————————— Address————————————————

—————————————————— Telephone No.————————————————Code————

NOTES

Draw in pre- and post-treatment chest X-ray pictures if taken

Pre-treatment

Date taken ....
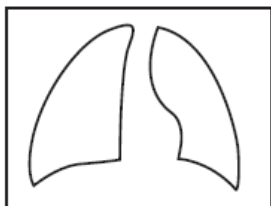
X-ray No ....

Post-treatment

Date taken ....

X-ray No ....
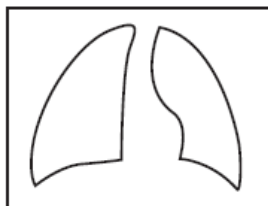
Date	Weight	Notes

PATIENT CONTACTS

	Name and Surename	Relationship	Age	Sputum		X-ray		Tuberculin test	
				Date	Resuit	Date	Result	Date	Result
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

Number of contacts traced cc   Number of contacts treated cc

TREATMENT OUTCOME

c(C)	**Cured**; Patient who is smear-negative at, or one month prior to, completion of treatment and on at least one previous osccasion
c(TC)	**Treatment completed** without bacteriologic proof of cure
c(TF)	**Treatment failure**, patient remains, or becomes again smear-positive at 5 months or later during treatment
c(D)	**Patient died** (any reason)
c(TI)	**Treatment interrupted** for 2 or more months
c(TRAN)	**Patient transferred** to another district; treatment outcome unknown
c(MVD)	Check here if patient **MOVED** to another facility in the **SAME** district

COMMENTS

_____
_____
_____
_____
_____
_____
_____
_____

d d m m y y y y

Discharged by (print name) _____ Date of dischrge cc/cc/cccc

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Appendix C: Data Requests

To: The Statistician General, Statistics South Africa

        Mr. Risenga Maluleke

From: Dr. Dan Kibuuka

        Auckland University of Technology

        National Health Scholarship Programme of the South African Medical Research Council and

        the National Department of Health.

Dear Sir,

Re: Request for access and use of TB Mortality data 2005 to 2015 for PhD research

I'm currently a registered PhD candidate with the Auckland University of Technology in New Zealand. My PhD programme is funded by the National Department of Health under the National Health Scholars Programme managed by the South African Medical Research Council. The aim of this programme is to increase the number of PhDs' in South Africa.

My research topic is: The role of surveillance systems in the epidemiology of Tuberculosis in South Africa. This research will be utilising deterministic and probabilistic approaches to link TB data sets in South Africa in order to determine if there's concordance between the key TB data sets.

In order to perform the linkages, TB mortality data with ID numbers, names, date of birth and addresses will be utilised. Also, hot spot analysis will be formed, and this will require access to TB data up to municipality level.

Data will be anonymised and in the final report, the data will be reported as aggregated data and no individuals will be identified.

I am aware of the confidentiality that this is required for this data and I'm willing to sign any data user agreement and abide by all the ethical issues for this kind of data.

Hoping that my request will be granted.

Kind regards,

Dr. Dan Kibuuka

15.08.2017

Data Use Policy

Data requests should be sent to the Research, Information, Monitoring, Evaluation & Surveillance (RIMES) Directorate of the National TB Control Programme (NTCP). A Data Use Agreement should be filled in to receive the data. Data requests processing may take up to 15 days, due to other commitments.

Instructions:

1. Fill in the dataset name as specified on the data request form.
2. Print, sign, scan, and email the completed form to DlamiS@health.gov.za or fax to +27 (0)866323254. The fax cover sheet must read: "Attention TB Data" and contain the name of the principal investigator as well as the name of the project associated with the data request.
3. The following documents must accompany this agreement:

    3.1. A clear and concise description of the intended purpose and method of analysis of the data (analysis plan)

    3.2. A list of the names and organizational affiliations of all those who will engage in this analysis

    3.3. A description of the means by which the investigator will restrict access to confidential TB data

    3.4. Students must also include a statement by a supervisor that he or she will ensure that the student will abide by terms listed below

Terms:

1. The investigator will neither release nor permit others to release the files or data therein to any person (including media and subcontractors) except with the written approval of the RIMES senior management.
2. The investigator will neither use nor permit others to use the data in any way other than listed in the original application for access to the data.
3. The investigator will ensure that the data are kept in a secured environment and that only authorized users have access to the data.
4. Every publication/report based on the data should carry an acknowledgement of the form: "Analysis based on data collected through the National TB Control Programme, Department of Health, South Africa".
5. The investigator will not release, or permit others to release, any data that identifies persons, households or other such micro-level data (up to and including the village level) directly or indirectly. Personal identifiers like ID number and patient names will be removed before data are provided
6. Once the dataset has served its indicated purpose it must be deleted/destroyed.
7. The dataset remains the property of the National TB Control Programme, RIMES and RIMES reserves the right to request the return of the dataset should any of the above conditions be violated.

Data Use Agreement

It is hereby agreed with the investigator(s): Dr. Dan Kibuuka

That she or he will have access to the following data set: TB data set 2005-2015.

The purpose of this agreement is to support the work of the study investigators, protect the confidentiality and related interests of the South African Department of Health (DoH) study participants, and ensure the long-term integrity of the DoH research program. The DoH reserves the right to add to, modify and/or amend this agreement at any time.

The following conditions will apply:

1. The investigator will neither release nor permit others to release the files or data therein to any person (including media and subcontractors) except with the written approval of the National TB Control Programme, RIMES senior management.
2. The investigator will neither use nor permit others to use the data in any way other than listed in the original application for access to the dataset.
3. The investigator will ensure that the data are kept in a secured environment and that only authorized users have access to the data.
4. Every publication or report based on the data should carry an acknowledgement of the DoH – for example "Analysis based on data collected through the South African Department of Health".
5. The investigator will not release, or permit others to release, any data that identifies persons, households, or other such micro-level data (up to and including the village level) directly or indirectly. Note: personal identifiers like ID number and patient names will be removed before data are provided.
6. Once the dataset has served its indicated purpose it must be deleted or destroyed.
7. The dataset remains the property of DoH and DoH reserves the right to request the return of the dataset should any of the above conditions be violated.
8. The following documents must accompany this agreement:

   8.1. A clear and concise description of the intended purpose and method of analysis of the data.

   8.2. A list of the names and organizational affiliations of all those who will engage in this analysis.

   8.3. A description of how the investigator will restrict access to confidential DoH data.

   8.4. In addition, students must also include a statement by a supervisor that he or she will ensure the student will abide by terms listed below.

Signed: _____ Date: 27.07.2017_____

Investigator(s)

Signed: _____ Date:_____

Sicelo Dlamini

Director: RIMES

Appendix D: Data Use Approval

STATS SA
STATISTICS SOUTH AFRICA

Enquiries: Ms Gwen Lehloenya

Reference: Access to TB Mortality data

Telephone: 012 310 9324

Email: gwen@statssa.gov.za

STATISTICS SOUTH AFRICA
DATA USER'S AGREEMENT: ACCESS TO 2005 – 2015 TUBERCULOSIS (TB) MORTALITY DATA

Statistics South Africa will allow you access to 2005-2015 mortality and causes of death data with identifiers compiled from death notification forms for the purpose of conducting research to estimate the actual TB prevalence in South Africa, through establishing a concordance TB data using datasets from Stats SA (causes of death), Department of Health (TB Surveillance data) and National Health Laboratory Services (Lab TB data).

The Data User must ensure that there is no misuse of the Data or breach of confidentiality and must agree to the following conditions:

1. The User agrees that he will not attempt to use, nor permit others to use the Data to establish the identity of any person included in any set.

2. The User agrees that he will keep the Data in a secure environment.

3. The Data may be used only by the User

4. The User agrees that any of the Data, or reliance by the User on any of the Data, is at the User's own risk, and that Statistics South Africa shall not be liable for any loss or damage howsoever arising as a result of such use.

5. The use of these Data in research communication, scholarly papers, journals and the like is encouraged, but the authors of these communications and documents agree to acknowledge/cite Statistics South Africa as the source of the Data, making it clear that the analysis and interpretation have been undertaken by the User. The User also agrees to submit to Statistics South Africa a copy of any research publication derived from these Data, for their information.

6. Non-adherence to the above conditions will result in:
   i. Render the User liable for the amount of ZAR 500 000 (Five hundred thousand Rands)
   ii. Statistics South Africa refusing to make available any datasets to the User in future.

7. Signatures of Users:

Name: Dr. Dan Kibuuka
Organisation: AUCKLAND UNIVERSITY OF TECHNOLOGY
Signature:
Signed on: 04·12·2017
Signed at: AUCKLAND

Mr. Risenga Maluleke

Statistician-General – Statistics South Africa

Date: 15/12/2017

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M Gmail

Re: Assistance to access TB and ARV Coverage data

Sicelo Dlamini <Sicelo.Dlamini@health.gov.za>   Wed, Aug 15, 2018 at 9:50 PM
To: "dan.kibuuka@gmail.com" <dan.kibuuka@gmail.com>
Cc: David Mametja <David.Mametja@health.gov.za>, Yogan Pillay <Yogan.Pillay@health.gov.za>

For the sake of progress, how will you get the data?

The volume is quite big and requires a big capacity medium. In addition, there will be a need to have these data password protected to ensure that the confidential patient data don't fall on the wrong hands.

Kind Regards,
Sicelo S. Dlamini
Director: Research, Information Monitoring, Evaluation & Surveillance (RIMES)
National TB Control & Management Cluster
Civitas Building Office N703
Corner of Bloed, Struben and Thabo Sehume Streets, Pretoria

Tel: 012-395 8813/8817

Cell: +27 79 873 7613

Alternative E-mail: scelo.sicelo@gmail.com

>>> Dan Kibuuka <dan.kibuuka@gmail.com> 08/09/18 11:32 AM >>>
[Quoted text hidden]

Appendix E: Death Notification Form

Notification / register of death / still birth (BI-1663)

REPUBLIC OF SOUTH AFRICA
DEPARTMENT OF HOME AFFAIRS
NOTIFICATION / REGISTER OF DEATH / STILL BIRTH

BI - 1663

in terms of the Births and Deaths Registration Act, 1992 (Act No. 51 of 1992)

Space for Bar Code

* Must be completed in black ink (please tick ✓ where applicable)
* Please refer to instructions

SERIAL No: A 0 1857265

FILE No: DATE:

A PARTICULARS OF DECEASED INDIVIDUAL / STILLBORN CHILD

Date of birth — Y Y Y Y M M D D

Identity number of deceased   Date of death — Y Y Y Y M M D D

Age at last birthday — years

Surname

Maiden Name (If female)   Sex

Forenames   If death occurred within 24 hours after birth No. of hours alive

MARITAL STATUS OF DECEASED   Single ☐   Civil Marriage ☐   Living as married ☐   Widowed ☐

Religious Law Marriage ☐   Divorced ☐   Customary Marriage ☐

Left thumb print of deceased

PLACE OF BIRTH (municipal district or country if abroad) _____

PLACE OF DEATH (City / Town / Village) _____

PLACE OF REGISTRATION OF DEATH _____

CITIZENSHIP OF DECEASED _____

B PARTICULARS OF INFORMANT

Identity number

Initials and Surname

Relationship to deceased   Parent ☐   Spouse ☐   Child ☐   Other kin ☐   Other (specify) ☐

Left thumb print of informant

Postal address

Postal Code   Dialling Code

Was the next of kin of the deceased a smoker* during the past five years?   Yes ☐   No ☐   Refuse to answer ☐   Telephone No.

Date _____   Signature

~~CANCELLED~~

C PARTICULARS OF FUNERAL UNDERTAKER

Initials and Surname

Designation No.   Place of burial / cremation _____

Office Stamp of Funeral Undertaker

Date _____   Signature

D CERTIFICATE BY ATTENDING MEDICAL PRACTITIONER / PROFESSIONAL NURSE

Postal Address

I, the undersigned, hereby certify that the deceased named in Section A, to the best of my knowledge and belief, died solely and exclusively due to NATURAL CAUSES specified in Section G ☐

I, the undersigned, am not in the position to certify that the deceased died exclusively due to natural causes ☐

Postal Code

SAMDC / SANC Reg. No.

_____ INITIALS AND SURNAME   SIGNATURE

Date signed — Y Y Y Y M M D D

CERTIFICATE BY DISTRICT SURGEON / FORENSIC PATHOLOGIST

I, the undersigned, hereby certify that a medicolegal post-mortem examination has been conducted on the body of the person whose particulars are given in Section A and that the body is no longer required for the purpose of the Inquest Act, 1959 (Act No. 58 of 1959) and that the cause of death is:

Postal Address

Unnatural ☐   Under investigation ☐

Natural (Cause of Death as indicated in Section G) ☐

Postal Code

Initials and Surname

Place of post-mortem _____   Date — Y Y Y Y M M D D   Mortuary Reference _____

Signature _____   Date signed — Y Y Y Y M M D D   SAMDC Reg. No.

E FOR OFFICIAL USE ONLY

Initials and Surname of Registrar

Registration of death approved and burial order issued

Office Stamp ▷

Address

Force No. / Designation No.

Persal No.

Date _____   Signature

* Someone who smokes tobacco on most days

PARAGON 225639 (14)

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Reverse side of Notification / register of death / still birth (BI-1663)

NOTIFICATION / REGISTER OF DEATH / STILL BIRTH
INFORMATION FOR MEDICAL AND HEALTH USE ONLY
(After completion *seal* to ensure <u>confidentiality</u>)

BI - 1663
Page 2

Space for Bar Code

SERIAL No:
A 01857265

FILE No: DATE:

F DEMOGRAPHIC DETAILS

Initials and Surname of deceased

Identity Number

Place of death   1. Hospital: (Inpatient ☐   ER/ Outpatient ☐   DOA ☐)   2. Nursing Home ☐   3. Home ☐   4. Other (Specify) ☐

FACILITY NAME (If not institution, give street and number) ....

Usual residential address of deceased # .... Suburb

Town / Village

Name of Plot, Farm, etc. .... Census Enumerator Area

Street name and number ....

Magist. Dist. ....

Deceased's Education (Specify ✓ only highest class completed/achieved)

Postal Code

None	Gr1	Gr2	Gr3	Gr4	Gr5	Gr6	Gr7	Gr8 Form 1	Gr9 Form 2	Gr10 Form 3 NTC1	Gr11 Form 4 NTC2	Gr12 Form 5 NTC3	Univ Tech	CODE

Province ....

Country ....

USUAL OCCUPATION OF DECEASED (give type of work done during most of working life. Do not use retired)

TYPE OF BUSINESS INDUSTRY (e.g. Mining, Farming) refer to instructions

Was the deceased a smoker* five years ago? (✓) :   Yes ☐   No ☐   Do not know ☐   Not applicable (minor) ☐

G MEDICAL CERTIFICATE OF CAUSE OF DEATH

FOR OFFICE USE ONLY

PART 1. Enter the disease, injuries or complications that caused the death. Do not enter the mode of dying, such as cardiac or respiratory arrest, shock, or heart failure. List only one cause on each line.

Approximate interval between onset and Death (Days/Months/Years)

ICD-10

IMMEDIATE CAUSE (Final disease or condition resulting in death)   a. ....
Due to (or as a consequence of)

Sequentially list conditions, if any, leading to immediate cause. Enter UNDERLYING CAUSE last (Disease or injury that initiated events resulting in death)   b. ....
Due to (or as a consequence of)

c. ....
Due to (or as a consequence of)

d. ....
Due to (or as a consequence of)

PART 2. Other significant conditions contributing to death but not resulting in the underlying cause given in Part 1. ....

If a **female**, was she pregnant 42 days prior to death? (✓) :   Yes ☐   No ☐

If **stillborn**, please write mass in grams ☐

Do you consider the deceased to be: African ☐   White ☐   Indian ☐   Coloured ☐   Other ☐ (Specify) ....

Method of ascertainment of cause of death:

1. Autopsy ☐   2. Opinion of attending medical practitioner ☐   3. Opinion of attending medical practitioner on duty ☐

4. Opinion of registered professional nurse ☐   5. Interview of family member ☐

6. Other ☐ (Specify) ....

Where someone lived on most days   * Someone who smokes tobacco on most days

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Appendix F: Mortality TB Raw Data

Table 4.13: *Mortality Tuberculosis Raw Data by Variable and Year for South Africa, 2005-2015 (n = 776 176)*

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Number of TB deaths	83,893	88,120	87,074	86,474	82,008	76,300	68,446	62,971	56,509	52,668	32,713	776, 176
Demographics **Gender**												
Male	38,606	40,534	40,073	39,393	36,796	33,920	29,835	26,979	23,793	21,696	12,607	344,232
Female	45,108	47,432	46,882	46,982	45,097	42,262	38,360	35,760	32,487	30,742	19,956	431,068
Unknown	3	2	0	0	11	4	0	0	3	6	1	30
Unspecified	176	152	119	99	104	114	251	232	226	224	149	1,846
Population group Black African	60,304	63,721	62,882	62,367	58,078	55,447	55,603	53,149	48,437	45,139	27,818	592,945
White	337	302	381	334	314	296	277	309	308	248	178	3,284
Indian Asian	208	269	292	231	177	211	215	226	184	174	127	2,314
Coloured	2,969	2,851	2,887	2,790	2,748	2,850	2,885	3,158	3,053	3,129	2,173	31,493
Other	97	112	76	42	47	43	55	70	55	55	40	692
Unknown	49	53	49	21	25	15	30	21	23	20	2	308
Unspecified	19,929	20,812	20,507	20,689	20,619	17,438	9,381	6,038	4,449	3,903	2,375	146,140

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Marital Status												
Never married	49,950	53,431	52,780	51,906	48,643	47,168	42,769	39,535	35,656	32,949	19,664	474,451
Married	12,243	12,617	12,259	12,421	11,887	12,045	11,279	10,471	9,485	8,903	5,764	119,374
Widowed	3,431	2,717	2,565	2,819	2,542	2,566	2,477	2,395	2,052	2,360	1,570	27,494
Divorced	3,648	3,552	3,546	3,571	3,309	802	710	728	648	682	383	21,579
Unknown	247	260	259	131	159	132	133	99	83	87	50	1,640
Level of education												
None	5,337	5,989	5,549	5,584	5,596	4,539	4,628	4,133	3,730	3,665	2,260	51,010
Grade R	1	0	0	0	0	3	211	274	202	176	225	1,092
Gr1	520	519	419	492	452	497	464	475	413	393	416	5,060
Gr2	816	918	883	880	812	825	817	740	693	660	580	8,624
Gr3	1,552	1,661	1,479	1,410	1,359	1,244	1,270	1,144	1,014	954	1,019	14,106
Gr4	2,667	2,739	2,434	2,448	2,326	2,228	2,085	1,943	1,732	1,692	920	23,214
Gr5	2,797	2,726	2,545	2,591	2,426	2,189	2,146	1,941	1,684	1,567	1,136	23,748
Gr6	2,948	2,928	2,882	2,966	2,647	2,568	2,344	2,236	2,022	1,836	1,570	26,947
Gr7	3,853	4,140	4,053	4,014	3,677	3,570	3,275	3,109	2,823	2,629	1,661	36,804
Gr8	3,707	3,902	3,842	3,771	3,697	3,535	3,368	3,087	2,934	2,683	1,127	35,653
Gr9	2,577	2,521	2,632	2,717	2,411	2,379	2,383	2,329	2,090	1,980	1,761	25,780
Gr10	3,235	3,655	3,709	3,867	3,591	3,483	3,395	3,411	3,039	2,946	1,382	35,713

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Gr11	2,041	2,492	2,759	2,915	2,763	2,767	2,729	2,882	2,489	2,528	2,758	29,123
Gr12	4,803	5,583	5,785	5,969	5,507	5,599	5,807	5,527	5,132	4,614	221	54,547
University	561	631	821	693	718	681	725	733	642	645	359	7,209
Unknown	161	211	184	177	386	977	1,549	2,149	2,147	2,415	1,645	12,001
Not applicable	1,436	2,441	2,851	2,241	2,635	1,889	1,318	1,088	945	903	574	18,321
Unspecified	44,881	45,064	44,247	43,739	41,005	37,327	29,932	25,770	22,778	20,382	13,099	368,224
Occupation group												
Armed forces, occupations unspecified and not elsewhere classified, and not economically active persons	940	72,150	70,854	70,886	67,875	62,741	56,384	51,933	46,942	43,890	27,591	572,186
Legislators, senior officials and managers	0	362	278	307	156	167	115	97	110	87	56	1,735
Professionals	5	546	610	585	496	490	594	552	499	408	248	5,033
Technicians and associate professionals	1	340	254	240	203	192	187	209	212	183	107	2,128
Clerks	6	454	464	545	447	380	269	256	211	174	107	3,313
Service workers, shop and market sales workers	4	1,406	1,460	1,390	1,240	1,243	1,270	1,234	1,050	988	573	11,858
Skilled agricultural and fishery workers	5	603	570	198	531	605	544	515	427	429	278	4,705

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Craft and related trade workers	14	1,970	1,835	1,762	1,800	1,626	1,065	968	871	774	489	13,174
Plant and machine operators and assemblers	9	1,438	1,636	1,559	1,319	1,302	1,517	1,482	1,292	1,152	721	13,427
Elementary occupations	39	5,579	5,952	6,047	5,301	4,950	4,672	4,178	3,522	3,365	1,887	45,492
Not applicable	82,870	3,272	3,161	2,955	2,640	2,604	1,829	1,547	1,373	1,218	656	104,125
Industry of Occupation												
Private households, exterritorial organisations, representatives of foreign governments and other activities not adequately defined	81,460	57,444	55,490	61,390	52,695	47,305	704	1,504	49,007	46,140	28,910	482,049
Agriculture, hunting, forestry and fishing	4	1,130	1,278	1,235	1,215	1,295	2,963	2,796	1,102	1,000	656	14,674
Mining and quarrying	15	1,363	1,385	1,382	1,132	1,014	925	871	745	708	453	9,993
Manufacturing	5	501	492	601	584	709	580	572	465	386	228	5,123
Electricity, gas and water supply	0	114	117	140	110	136	194	184	159	184	91	1,429
Construction	6	655	870	863	839	774	851	884	820	825	468	7,855
Wholesale and retail trade, repair of motor vehicles, motor cycles and personal and households goods, hotels and restaurants	7	962	1,109	1,155	1,088	1,100	4,098	4,431	863	808	408	16,029
Transport, storage and communication	6	560	704	627	568	719	11,804	11,642	571	581	350	28,132

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Financial intermediation, insurance, real estate and business services	8	423	481	491	442	806	39,405	33,590	200	168	86	76,100
Community, social and personal services	171	21,696	21,987	15,635	20,695	19,838	5,093	4,950	1,204	650	407	112,326
Not applicable	2,211	3,272	3,161	2,955	2,640	2,604	1,829	1,547	1,373	1,218	656	23,466
Smoking status												
Yes	10,976	11,253	11,201	11,128	10,686	10,755	11,786	12,776	11,944	12,031	7,941	122,477
No	22,410	24,053	24,082	23,824	22,315	21,570	23,101	23,549	21,823	20,607	12,654	239,988
Do not know	3,961	3,925	4,009	3,580	3,026	2,906	3,124	3,364	3,018	2,871	1,819	35,603
Not applicable	2,424	3,375	3,281	3,064	3,028	2,751	1,940	1,679	1,470	1,429	733	25,174
Unknown	199	222	202	155	126	100	192	44	29	54	7	1,330
Unspecified	43,923	45,292	44,299	44,723	42,827	38,218	28,303	21,559	18,225	15,676	9,559	352,604
Method of ascertainment of death												
Post-mortem examination	31,497	33,946	33,783	35,536	32,167	4,027	13,732	17,549	16,964	16,016	9,626	244,843
Opinion of attending medical practitioner	17,365	19,851	19,074	19,857	19,191	27,430	21,260	16,265	14,144	12,831	7,344	194,612
Opinion of attending medical practitioner on duty	3,627	2,749	2,435	2,637	2,876	15,846	7,602	3,880	2,455	1,690	803	46,600
Opinion of registered professional nurse	11,678	11,583	11,378	10,749	9,909	3,343	4,694	5,730	5,290	5,086	3,993	83,433

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Interview of family member	1,500	1,273	1,499	1,619	1,362	7,889	4,319	2,312	1,255	959	564	24,551
Other	2	2	2	8	19	839	503	389	318	322	237	2,641
Autopsy results may be available later	3,436	3,717	3,701	107	304	0	0	0	0	0	0	11,265
Autopsy not performed	14,737	14,943	15,126	15,864	15,854	0	1	0	0	0	0	76,525
Unknown	0	0	1	0	7	374	523	493	360	325	150	2,233
Unspecified	51	56	75	97	319	16,552	15,812	16,353	15,723	15,439	9,996	90,473
Place or Institution of death												
Hospital	50,809	53,926	53,717	56,673	54,395	50,130	44,284	41,203	38,487	35,590	20,784	499,998
Emergency room/Outpatient	1,395	1,502	1,435	1,241	1,368	1,271	965	1,055	951	946	520	12,649
Dead on arrival	1,410	1,522	1,279	1,158	1,066	962	747	708	676	688	532	10,748
Nursing home	853	808	892	863	700	737	629	522	582	433	449	7,468
Home	19,761	20,013	19,854	17,794	16,501	14,604	11,792	10,673	8,783	8,484	6,455	154,714
Other	1,323	1,221	1,223	1,020	943	777	641	573	598	668	444	9,431
Unknown	230	276	196	84	55	54	52	51	45	31	11	1,085
Unspecified	8,112	8,852	8,478	7,641	6,980	7,765	9,336	8,186	6,387	5,828	3,518	81,083

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Province of death												
Eastern Cape	12,260	12,363	11,757	11,964	12,302	11,998	10,094	9,045	8,620	8,814	5,730	11,4947
Gauteng	6,432	6,386	6,288	6,109	5,736	5,379	4,550	4,032	3,565	3,421	2,042	53,940
KwaZulu-Natal	11,038	11,299	10,938	11,543	11,228	10,631	10,009	9,889	9,096	8,380	5,117	109,168
Limpopo	22,229	23,229	23,474	22,605	21,616	20,096	18,642	17,175	14,947	12,375	7,500	203,888
Mpumalanga	3,969	4,494	4,935	4,796	4,969	4,634	4,946	4,976	4,503	4,410	3,039	49,671
North West	5,777	6,659	6,730	6,569	6,911	6,339	6,192	5,697	4,965	4,679	2,699	63,217
Northern Cape	4,990	5,019	5,086	5,188	5,272	5,298	5,024	4,563	4,071	4,152	2,757	51,420
Western Cape	3,633	3,825	4,218	4,323	4,492	4,691	4,704	4,643	4,296	4,191	2,497	45,513
Outside South Africa	64	76	94	124	130	23	91	105	114	107	70	998
Unspecified	11,337	252	316	315	6,855	5,308	2,640	1,017	580	460	263	11,337

Appendix G: TB Notifications and Deaths, 2005 and 2010

Table 5.15: *Unadjusted Tuberculosis Notification Rates per 100,000 Population by District Municipality and Sex in South Africa, 2005*

District municipality	Overall unadjusted TB notification rates (per 100 000)	Unadjusted TB notification rates male (per 100 000)	Unadjusted TB notification rates female (per 100 000)
Alfred Nzo	521.9	600.8	374.9
Amajuba	786.8	964.3	687.4
Amathole	413.1	470.3	319.3
Bojanala Platinum	678.9	816.1	529.0
Buffalo City	1025.3	1122.4	854.3
Sarah Baartman	1301.7	1320.4	992.2
Cape Town Metro	696.7	801.6	597.4
Cape Winelands	1331.3	1961.2	1548.8
Capricorn	270.7	320.4	227.3
Central Karoo	605.6	609.6	601.7
Chris Hani	597.9	685.3	482.6
Dr. K Kaunda	2054.1	3243.0	2536.9
Eden	1146.6	1357.7	944.2
Ehlanzeni	0.1	0.1	0.0
Ekurhuleni Metro	517.3	566.5	465.1
Fezile Dabi	565.5	353.2	268.1
Frances Baard	920.2	1094.0	762.2
Gert Sibande	0.7	1.2	0.2
Greater Sekhukhune	173.9	207.1	146.1
John Taolo Gaetsewe	119.1	127.4	111.4
Joe Gqabi	614.8	688.2	499.9
Johannesburg Metro	612.5	672.0	551.6
Lejweleputswa	1281.4	1656.3	998.1

District municipality	Overall unadjusted TB notification rates (per 100 000)	Unadjusted TB notification rates male (per 100 000)	Unadjusted TB notification rates female (per 100 000)
Mangaung Metro	792.3	895.1	695.9
Mopani	358.7	423.0	304.1
Namakwa	752.1	869.7	628.8
Nelson Mandela Metro	1416.1	1532.7	1130.9
Ngaka Modiri Molema	694.5	745.5	665.9
Nkangala	0.1	0.0	0.2
OR Tambo	966.9	1109.2	794.3
Overberg	1264.1	1522.4	1001.6
Pixley Ka Seme	1064.3	1328.5	644.1
Ruth S Mompati	1163.5	1182.5	1145.7
Sedibeng	501.0	555.4	445.4
Sisonke	944.9	1060.0	806.5
Siyanda	2001.3	2194.2	1809.8
Thabo Mofutsanyane	661.7	739.0	497.1
Tshwane Metro	483.8	555.3	411.7
Ugu	547.6	666.7	446.8
Vhembe	331.0	426.4	251.9
Waterberg	524.0	646.5	406.3
West Coast	1071.6	1375.5	815.1
West Rand	819.6	1126.9	506.4
Xhariep	1059.4	1196.1	928.6
Zululand	1134.4	1261.0	1024.9
eThekwini Metro	943.5	1100.0	822.5
iLembe	1331.9	1449.4	1227.8
uMgungundlovu	1443.7	1561.7	1337.8
uMkhanyakude	637.4	715.4	573.7
uMzinyathi	1281.4	1492.9	1112.0

District municipality	Overall unadjusted TB notification rates (per 100 000)	Unadjusted TB notification rates male (per 100 000)	Unadjusted TB notification rates female (per 100 000)
uThukela	0.0	0.0	0.0
uThungulu	0.1	0.0	0.0

Table 5.16: *Unadjusted Tuberculosis Notification Rates per 100,000 Population by District Municipality and Sex in South Africa, 2010*

District municipality	Overall unadjusted TB notification rates (per 100 000)	Unadjusted TB notification rates male (per 100 000)	Unadjusted TB notification rates female (per 100 000)
Alfred Nzo	645.6	659.6	559.0
Amajuba	1171.7	1297.7	1065.6
Amathole	715.5	732.6	616.0
Bojanala Platinum	967.4	1110.4	811.0
Buffalo City	1160.6	1212.1	941.6
Sarah Baartman	1611.2	1561.4	1250.5
Cape Town Metro	682.2	735.1	631.7
Cape Winelands	1235.4	1384.3	1089.8
Capricorn	595.1	693.9	538.4
Central Karoo	986.4	1045.9	930.0
Chris Hani	1013.5	1095.5	805.6
Dr. K Kaunda	2063.8	2152.7	1831.2
Eden	1196.3	1352.1	1046.8
Ehlanzeni	1162.9	1253.5	1081.2
Ekurhuleni Metro	116.0	119.2	112.5
Fezile Dabi	966.7	1044.3	889.5
Frances Baard	1272.8	1416.2	1137.8
Gert Sibande	1006.9	1095.0	922.0
Greater Sekhukhune	497.4	557.6	445.4
John Taolo Gaetsewe	607.6	697.3	528.8
Joe Gqabi	982.8	993.7	856.0
Johannesburg Metro	127.2	132.3	122.1
Lejweleputswa	1338.5	1542.6	1066.4
Mangaung Metro	1143.9	1269.0	1033.8
Mopani	607.8	632.4	586.3

District municipality	Overall unadjusted TB notification rates (per 100 000)	Unadjusted TB notification rates male (per 100 000)	Unadjusted TB notification rates female (per 100 000)
Namakwa	1034.1	1161.3	903.6
Nelson Mandela Metro	1296.8	1350.6	989.7
Ngaka Modiri Molema	1238.1	1329.4	1085.3
Nkangala	611.3	680.6	542.5
OR Tambo	1380.6	1429.7	1228.1
Overberg	1248.0	1408.2	1085.1
Pixley Ka Seme	1350.7	1430.5	1273.1
Ruth S Mompati	1475.3	1593.6	1366.8
Sedibeng	156.3	172.2	139.7
Sisonke	1814.9	1925.9	1556.9
Siyanda	1521.0	1678.1	1363.8
Thabo Mofutsanyane	937.4	1011.9	854.5
Tshwane Metro	280.6	294.3	266.8
Ugu	2335.2	2638.6	2073.1
Vhembe	453.2	538.7	380.3
Waterberg	911.1	1011.3	811.5
West Coast	1265.4	1400.3	1131.4
West Rand	168.2	211.1	124.5
Xhariep	1358.0	1428.3	1290.6
Zululand	1436.2	1466.0	1410.1
eThekwini Metro	1642.6	1754.1	1551.0
iLembe	1390.3	1502.5	1290.2
uMgungundlovu	1641.5	1738.4	1554.5
uMkhanyakude	1791.0	1969.9	1649.6
uMzinyathi	1504.2	1723.1	1323.6
uThukela	1208.4	1361.9	1077.1
uThungulu	1730.2	1905.4	1579.8

Table 5.17: *Age sex standardised Tuberculosis notification rates per 100,000 population by District Municipality and Sex in South Africa, 2005*

District municipality	Overall age sex standardised TB notification rates (per 100 000)	Age sex standardised TB notification rates male (per 100 000)	Age sex standardised TB notification rates female (per 100 000)
Alfred Nzo	788.7	1003.6	550.8
Amajuba	1156.3	1620.7	892.8
Amathole	557.2	713.7	432.8
Bojanala Platinum	696.0	840.6	535.2
Buffalo City	1172.8	1360.7	1000.7
Sarah Baartman	1391.6	1609.7	1180.1
Cape Town Metro	708.9	823.4	600.6
Cape Winelands	1752.9	1981.9	1531.5
Capricorn	383.9	470.7	314.1
Central Karoo	623.1	641.8	605.8
Chris Hani	819.7	1058.5	646.1
Dr. K Kaunda	2902.9	3218.2	2497.3
Eden	1166.3	1397.8	944.1
Ehlanzeni	0.1	0.2	0.0
Ekurhuleni Metro	601.9	652.5	545.5
Fezile Dabi	302.1	327.3	272.1
Frances Baard	1088.3	1287.3	904.9
Gert Sibande	0.9	1.6	0.4
Greater Sekhukhune	257.6	335.1	203.5
John Taolo Gaetsewe	146.8	154.4	139.3
Joe Gqabi	895.0	1087.0	729.6
Johannesburg Metro	695.7	758.3	629.3
Lejweleputswa	1529.1	1992.8	1194.8
Mangaung Metro	970.9	1122.9	831.0
Mopani	487.1	604.2	395.8

District municipality	Overall age sex standardised TB notification rates (per 100 000)	Age sex standardised TB notification rates male (per 100 000)	Age sex standardised TB notification rates female (per 100 000)
Namakwa	853.0	998.4	698.2
Nelson Mandela Metro	1546.3	1806.2	1303.1
Ngaka Modiri Molema	728.5	775.4	683.3
Nkangala	0.1	0.0	0.1
OR Tambo	1352.5	1733.9	1074.9
Overberg	1276.0	1545.9	997.8
Pixley Ka Seme	1246.0	1342.4	1151.3
Ruth S Mompati	1205.6	1234.5	1176.4
Sedibeng	592.8	656.2	619.3
Sisonke	1378.7	1662.1	1186.3
Siyanda	2295.1	2552.3	2036.8
Thabo Mofutsanyane	1114.9	979.6	879.8
Tshwane Metro	561.4	640.4	479.3
Ugu	761.4	966.9	603.0
Vhembe	451.4	629.9	321.1
Waterberg	690.9	875.0	520.0
West Coast	1064.9	1411.7	808.6
West Rand	954.8	1249.6	624.1
Xhariep	1320.1	1487.6	1148.2
Zululand	1662.8	1951.6	1438.1
eThekwini metro	1179.0	1405.2	1009.1
iLembe	1739.6	1937.6	1570.3
uMgungundlovu	1815.2	1997.3	1651.3
uMkhanyakude	913.2	1112.8	776.1
uMzinyathi	1928.5	2486.7	1566.9
uThukela	0.0	0.0	0.0
uThungulu	0.0	0.0	0.0

Table 5.18: *Age Sex Standardised Tuberculosis Notification Rates per 100,000 Population by District Municipality and Sex in South Africa, 2010*

District municipality	Overall age sex standardised TB notification rates (per 100 000)	Age sex standardised TB notification rates male (per 100 000)	Age sex standardised TB notification rates gemale (per 100 000)
Alfred Nzo	870.7	1051.5	752.6
Amajuba	1640.5	2106.9	1352.9
Amathole	927.3	1029.8	843.5
Bojanala Platinum	981.4	1121.3	822.5
Buffalo City	1256.4	1406.2	1114.3
Sarah Baartman	1691.1	1863.7	1517.0
Cape Town Metro	685.7	740.3	632.8
Cape Winelands	1219.2	1374.4	1067.2
Capricorn	774.4	866.6	715.1
Central Karoo	1016.7	1085.0	950.9
Chris Hani	1296.6	1571.1	1082.6
Dr. K Kaunda	1992.8	2133.1	1837.2
Eden	1210.1	1375.2	1051.2
Ehlanzeni	1481.1	1603.3	1372.7
Ekurhuleni Metro	132.1	133.8	129.8
Fezile Dabi	1140.4	1218.5	1056.0
Frances Baard	1433.4	1581.4	1287.9
Gert Sibande	1220.1	1320.4	1118.1
Greater Sekhukhune	657.2	752.4	589.3
John Taolo Gaetsewe	728.0	825.0	650.8
Joe Gqabi	1279.6	1369.3	1197.1
Johannesburg Metro	142.7	145.5	139.6
Lejweleputswa	1482.0	1724.6	1232.2
Mangaung Metro	1342.2	1478.9	1211.3
Mopani	738.7	773.8	708.2

District municipality	Overall age sex standardised TB notification rates (per 100 000)	Age sex standardised TB notification rates male (per 100 000)	Age sex standardised TB notification rates gemale (per 100 000)
Namakwa	1113.8	1241.3	978.9
Nelson Mandela Metro	1341.5	1543.5	1150.0
Ngaka Modiri Molema	1214.7	1350.9	1090.9
Nkangala	729.2	800.4	655.7
OR Tambo	1760.0	1975.1	1595.8
Overberg	1239.3	1409.4	1063.4
Pixley Ka Seme	1538.7	1608.0	1472.9
Ruth S Mompati	1520.5	1655.5	1397.7
Sedibeng	184.0	198.4	168.3
Sisonke	2260.3	2600.2	1994.6
Siyanda	1675.2	1836.4	1509.5
Thabo Mofutsanyane	1118.2	1236.4	1017.3
Tshwane Metro	311.6	323.3	298.9
Ugu	3186.5	3722.3	2756.2
Vhembe	562.8	682.1	466.2
Waterberg	1188.2	1208.7	983.1
West Coast	1266.3	1413.2	1119.5
West Rand	192.7	230.0	152.5
Xhariep	1643.2	1712.9	1569.2
Zululand	1967.4	2070.1	1887.4
eThekwini Metro	1916.3	2053.7	1807.0
iLembe	1786.6	1951.7	1641.9
uMgungundlovu	1979.4	2120.8	1849.3
uMkhanyakude	2402.4	2772.8	2150.3
uMzinyathi	2123.4	2567.1	1801.2
uThukela	1611.8	1855.8	1411.5
uThungulu	2217.0	2500.8	1987.9

Table 5.19: *Unadjusted Tuberculosis Death Rates per 100,000 Population by District Municipality and Sex in South Africa, 2005*

District municipality	Overall unadjusted TB death rates (per 100 000)	Unadjusted TB death rates male (per 100 000)	Unadjusted TB death rates female (per 100 000)
Alfred Nzo	140.3	170.4	114.3
Amajuba	234.1	261.4	210.5
Amathole	244.8	281.8	210.3
Bojanala Platinum	87.8	96.8	78.0
Buffalo City	243.5	235.2	250.4
Sarah Baartman	560.8	655.5	469.7
Cape Town Metro	58.6	72.2	45.7
Cape Winelands	100.2	127.9	72.6
Capricorn	123.2	122.8	88.1
Central Karoo	112.2	125.0	99.8
Chris Hani	182.5	111.0	50.1
Dr. K Kaunda	281.4	311.2	251.4
Eden	115.1	140.4	91.0
Ehlanzeni	161.4	171.5	152.2
Ekurhuleni Metro	117.7	126.5	108.3
Fezile Dabi	162.5	177.8	147.2
Frances Baard	249.1	288.3	213.4
Gert Sibande	220.3	234.0	207.5
Greater Sekhukhune	85.9	96.0	66.5
John Taolo Gaetsewe	133.5	157.2	111.4
Joe Gqabi	196.6	221.7	172.0
Johannesburg Metro	89.2	98.3	80.0
Lejweleputswa	345.3	396.0	295.1
Mangaung Metro	185.9	197.5	175.0
Mopani	78.5	94.6	64.4

District municipality	Overall unadjusted TB death rates (per 100 000)	Unadjusted TB death rates male (per 100 000)	Unadjusted TB death rates female (per 100 000)
Namakwa	87.4	106.3	65.8
Nelson Mandela Metro	275.9	313.7	240.6
Ngaka Modiri Molema	363.9	241.8	178.8
Nkangala	95.0	122.3	97.9
OR Tambo	113.7	130.0	99.6
Overberg	64.5	79.8	48.9
Pixley Ka Seme	206.2	215.8	195.8
Ruth S Mompati	223.9	239.2	209.1
Sedibeng	143.1	161.0	124.9
Sisonke	172.2	209.7	139.7
Siyanda	181.0	198.5	163.6
Thabo Mofutsanyane	236.8	271.2	169.8
Tshwane Metro	82.2	91.8	72.1
Ugu	295.2	343.3	254.0
Vhembe	50.9	64.9	39.1
Waterberg	71.4	75.0	67.6
West Coast	89.6	117.4	65.1
West Rand	175.5	197.1	152.4
Xhariep	245.4	266.7	225.0
Zululand	210.4	232.5	189.7
eThekwini Metro	189.3	193.0	185.7
iLembe	266.8	306.7	231.5
uMgungundlovu	312.0	348.6	278.7
uMkhanyakude	209.5	229.5	192.9
uMzinyathi	332.8	408.5	271.1
uThukela	260.3	315.7	212.7
uThungulu	146.3	163.0	131.2

Table 5.20: *Unadjusted Tuberculosis Death Rates per 100,000 Population by District Municipality and Sex in South Africa, 2010*

District municipality	Overall unadjusted TB death rates (per 100 000)	Unadjusted TB death rates male (per 100 000)	Unadjusted TB death rates female (per 100 000)
Alfred Nzo	97.4	117.2	81.5
Amajuba	185.2	210.8	163.7
Amathole	278.7	324.9	235.7
Bojanala Platinum	95.5	105.1	85.0
Buffalo City	249.9	277.9	223.95
Sarah Baartman	214.4	237.7	188.8
Cape Town Metro	73.8	83.3	64.5
Cape Winelands	100.2	128.7	72.4
Capricorn	111.5	115.3	87.3
Central Karoo	132.9	166.7	100.8
Chris Hani	188.5	208.7	141.4
Dr. K Kaunda	207.9	228.2	187.5
Eden	91.6	107.1	76.7
Ehlanzeni	185.3	214.3	159.0
Ekurhuleni Metro	97.2	106.2	87.1
Fezile Dabi	148.2	174.7	121.9
Frances Baard	124.8	138.5	111.9
Gert Sibande	171.5	194.2	149.7
Greater Sekhukhune	80.0	89.2	72.1
John Taolo Gaetsewe	119.9	149.5	94.0
Joe Gqabi	218.7	243.2	195.1
Johannesburg Metro	65.7	70.5	60.6
Lejweleputswa	226.6	263.8	189.5
Mangaung Metro	147.3	179.2	117.2
Mopani	92.4	103.1	83.0

District municipality	Overall unadjusted TB death rates (per 100 000)	Unadjusted TB death rates male (per 100 000)	Unadjusted TB death rates female (per 100 000)
Namakwa	62.3	73.1	51.2
Nelson Mandela Metro	155.8	186.2	127.0
Ngaka Modiri Molema	157.2	178.3	137.9
Nkangala	102.5	119.9	98.9
OR Tambo	153.1	165.9	141.6
Overberg	83.9	102.3	64.4
Pixley Ka Seme	286.2	338.1	235.8
Ruth S Mompati	213.3	246.5	182.9
Sedibeng	151.7	183.1	118.5
Sisonke	291.7	347.1	243.6
Siyanda	159.3	196.3	122.3
Thabo Mofutsanyane	196.7	241.6	157.5
Tshwane Metro	67.3	79.6	54.6
Ugu	363.3	424.1	310.4
Vhembe	56.4	73.3	49.3
Waterberg	85.7	99.4	72.0
West Coast	119.2	142.5	96.1
West Rand	128.8	153.7	103.5
Xhariep	365.7	404.3	328.7
Zululand	260.3	298.5	225.3
eThekwini Metro	117.8	125.2	110.5
iLembe	204.8	234.9	177.6
uMgungundlovu	197.2	240.5	158.0
uMkhanyakude	214.7	251.0	184.5
uMzinyathi	244.9	298.0	200.7
uThukela	234.4	271.6	202.7
uThungulu	139.8	359.2	246.0

Table 5.21: *Age Sex Standardised Tuberculosis Death Rates per 100,000 Population by District Municipality and Sex in South Africa, 2005*

District municipality	Overall age sex standardised TB death rates (per 100 000)	Age sex standardised TB death rates male (per 100 000)	Age sex standardised TB death rates female (per 100 000)
Alfred Nzo	229.7	299.4	181.2
Amajuba	363.0	469.6	295.8
Amathole	371.8	435.4	317.9
Bojanala Platinum	90.3	99.7	79.7
Buffalo City	297.5	281.2	311.1
Sarah Baartman	200.7	226.9	175.1
Cape Town Metro	61.1	75.8	47.0
Cape Winelands	105.9	136.0	76.1
Capricorn	155.3	186.5	129.7
Central Karoo	121.2	136.2	106.8
Chris Hani	199.9	232.0	177.2
Dr. K Kaunda	284.8	309.9	256.2
Eden	122.5	150.1	95.5
Ehlanzeni	227.3	247.9	209.4
Ekurhuleni Metro	138.9	146.0	130.8
Fezile Dabi	211.1	226.3	194.3
Frances Baard	313.7	357.7	273.0
Gert Sibande	297.8	316.8	278.4
Greater Sekhukhune	121.1	152.0	99.1
John Taolo Gaetsewe	179.0	204.0	155.1
Joe Gqabi	298.4	330.2	269.0
Johannesburg Metro	103.9	113.2	93.9
Lejweleputswa	431.0	486.2	373.6
Mangaung Metro	244.1	261.0	227.7
Mopani	108.2	134.0	87.4

District municipality	Overall age sex standardised TB death rates (per 100 000)	Age sex standardised TB death rates male (per 100 000)	Age sex standardised TB death rates female (per 100 000)
Namakwa	101.8	123.6	78.4
Nelson Mandela Metro	328.3	366.3	291.8
Ngaka Modiri Molema	143.9	159.3	129.1
Nkangala	147.2	164.1	130.1
OR Tambo	167.9	198.5	144.8
Overberg	68.4	84.7	51.1
Pixley Ka Seme	260.9	271.3	250.8
Ruth S Mompati	234.9	252.8	217.7
Sedibeng	170.1	186.8	179.0
Sisonke	277.5	356.9	217.1
Siyanda	220.2	237.2	202.4
Thabo Mofutsanyane	442.9	379.4	338.3
Tshwane Metro	98.5	105.9	90.4
Ugu	434.0	528.4	362.0
Vhembe	72.6	96.8	54.5
Waterberg	100.5	106.1	94.7
West Coast	97.0	129.5	67.9
West Rand	204.5	216.7	191.4
Xhariep	337.6	351.9	322.3
Zululand	340.4	395.9	297.1
eThekwini Metro	244.4	249.2	239.1
iLembe	373.9	434.3	322.2
uMgungundlovu	414.3	467.2	366.4
uMkhanyakude	335.7	391.4	297.7
uMzinyathi	546.1	734.7	423.4
uThukela	372.2	466.9	297.1
uThungulu	218.5	247.1	194.9

Table 5.22: *Age Sex Standardised Tuberculosis Death Rates per 100,000 Population by District Municipality and Sex in South Africa, 2010*

District municipality	Overall age sex standardised TB death rates (per 100 000)	Age sex standardised TB death rates male (per 100 000)	Age sex standardised TB death rates female (per 100 000)
Alfred Nzo	149.6	199.3	116.6
Amajuba	272.9	365.5	215.9
Amathole	399.7	460.5	350.7
Bojanala Platinum	136.9	105.8	86.7
Buffalo City	289.5	312.3	268.2
Sarah Baartman	252.7	269.8	234.8
Cape Town Metro	74.6	84.1	65.2
Cape Winelands	103.4	133.2	74.3
Capricorn	138.0	152.6	125.2
Central Karoo	140.2	175.8	106.8
Chris Hani	241.3	295.7	200.4
Dr. K Kaunda	210.2	226.6	192.0
Eden	95.3	112.0	79.3
Ehlanzeni	234.9	270.8	202.9
Ekurhuleni Metro	109.6	116.4	101.6
Fezile Dabi	179.4	203.2	153.6
Frances Baard	148.3	158.8	138.3
Gert Sibande	216.1	243.0	189.0
Greater Sekhukhune	110.7	126.9	99.5
John Taolo Gaetsewe	153.2	182.8	131.2
Joe Gqabi	307.3	325.9	291.0
Johannesburg Metro	74.3	77.5	70.7
Lejweleputswa	269.4	308.6	229.0
Mangaung Metro	177.3	212.6	143.8
Mopani	119.5	131.2	109.2

District municipality	Overall age sex standardised TB death rates (per 100 000)	Age sex standardised TB death rates male (per 100 000)	Age sex standardised TB death rates female (per 100 000)
Namakwa	69.9	83.1	55.7
Nelson Mandela Metro	176.6	202.3	152.2
Ngaka Modiri Molema	161.4	184.1	141.1
Nkangala	130.2	138.6	121.3
OR Tambo	209.4	233.5	191.1
Overberg	88.3	108.7	66.9
Pixley Ka Seme	355.2	406.6	304.8
Ruth S Mompati	228.3	265.0	195.1
Sedibeng	176.3	204.1	145.9
Sisonke	428.8	519.2	357.8
Siyanda	187.2	221.7	151.8
Thabo Mofutsanyane	248.7	304.9	200.7
Tshwane Metro	98.2	86.8	64.9
Ugu	516.0	615.0	438.4
Vhembe	78.5	94.1	65.8
Waterberg	158.6	121.6	93.1
West Coast	126.0	151.3	100.7
West Rand	147.1	167.2	125.2
Xhariep	492.2	524.3	459.2
Zululand	375.5	441.5	321.8
eThekwini Metro	140.3	147.5	133.1
iLembe	268.7	307.4	234.6
uMgungundlovu	249.0	302.3	200.4
uMkhanyakude	302.3	376.1	252.0
uMzinyathi	361.6	464.9	287.4
uThukela	323.0	371.8	282.9
uThungulu	190.8	246.6	145.3

Appendix H: Extracted Data Management, Monitoring, and Evaluation Recommendations

Table 7.3: *Extracted Data Management, Monitoring and Evaluation Recommendations from the Tuberculosis or the Human Immunodeficiency Virus/Antiretroviral Treatment Policy Guidelines, South Africa, 2004 -2016*

Title of the guideline	Year	Extracted data management, monitoring and evaluation recommendations
The South African National Tuberculosis Control Programme Practical Guidelines	2004	Accurate keeping of records on all individual patients is essential for planning. Standardised forms are utilised by the NTCP are Case Identification and Follow Up Register (GW 20/13), Clinic/Hospital card (GW 20/12), Client treatment card (GW 20/15) and Tuberculosis Register (GW 20/11). The information collected at facility level in the clinic or hospital card is entered into the register and all these have to be updated regularly. Analysis and validation of the data should be done at facility level with facility reports completed quarterly. From the facilities data is passed on to the sub district where it is collated and analysed. Data is passed on to the sub district where it is collated and analysed.
National Antiretroviral Treatment Guidelines	2004	There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines.
National Tuberculosis Control Management Guidelines	2009	Standard tools used in The National TB Control Programme are Case Identification and Follow Up Register (GW 20/13), Clinic/Hospital card (GW 20/12), Client treatment card (GW 20/15) and Tuberculosis Register (GW 20/11). Information that is submitted to the sub/district is to be entered into the electronic register and data validation and analysis to be done using the ETR.

Title of the guideline	Year	Extracted data management, monitoring and evaluation recommendations
		During the third week after end of the month, the TB Coordinator and data capturer / health information need to run data checks and ensure that all the data that has been captured is correct and complete.
		Subdistrict, District, Province and National to run checks to validate data.
		Data is transmitted electronically from the sub/district level to the provincial level where it is aggregated and analysed before it is passed on to the national level.
		Data needs to be disaggregated and analysed at facility level.
National Tuberculosis Management Guidelines	2014	Standard tools used in The National TB Control Programme are Case Identification and Follow Up Register (GW 20/13), Clinic/Hospital card (GW 20/12), Client treatment card (GW 20/15) Tuberculosis Register (GW 20/11), Laboratory request form for Sputum Examination, Transfer form (GW20/14) and TB symptom screening tool.
		Facilities must conduct a cascade analysis of the data from suspicion to treatment outcome on a monthly and quarterly basis.
		Information that is submitted to the sub/district is to be entered into the electronic register and data validation and analysis to be done using the ETR.
		Data is transmitted electronically from the sub/district level to the provincial level where it is aggregated and analysed before it is passed on to the national level.
		During the third week after end of the month, the TB Coordinator and data capturer / health information need to run data checks and ensure that all the data that has been captured is correct and complete.
		Subdistrict, District, Province and National to run checks to validate data.

Title of the guideline	Year	Extracted data management, monitoring and evaluation recommendations
		Data needs to be collated and analysed at facility level because this is the level at which quality improvements have to be made.
The South African Antiretroviral Treatment Guidelines	2013	There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines.
The South African Antiretroviral Treatment Guidelines	2010	There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines.
Guidelines for the Management of Tuberculosis in Children	2013	Accurate recording, data collation and analysis at different levels is important for improved epidemiological surveillance, planning and organisation of services, quantification of medicines drug formulations and budgeting.

Data of all children, who have been screened for TB must be collated on a daily basis using the daily summary sheet.

Children who are started on TB treatment, must be entered into the facility-based TB treatment register (GW 20/11). All fields in the registers must be completed. The data must be disaggregated by HIV status, age groups and type of disease.

At the end of the treatment, the treatment outcome must be recorded in the TB register. Accurate recording at the facility level is important for proper evaluation of the programme.

All children diagnosed with TB and are HIV negative or HIV status is unknown must have been tested for HIV on completion of TB treatment. The HIV status, Cotrimoxazole and ART information must be entered in the TB treatment register. |
| The South African Antiretroviral Treatment Guidelines, PMTCT guidelines | 2013 | There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines. |

Title of the guideline	Year	Extracted data management, monitoring and evaluation recommendations
National Consolidated Guidelines for the Prevention of Mother to Child Transmission of HIV (PMTCT) and Management of HIV in Children, Adolescents and Adults	2015	To facilitate a standardised and systematic monitoring, it is compulsory for ART (including paediatric and antenatal care) service points to utilise the approved monitoring data collection tools.
		Clinicians treating patients should ensure that all required data collection tools are completed in detail.
		The responsibility for data collection, analysis, management, reporting and usage rests at four levels (facility/hospital, sub-district/district, Province and national).
		ART (including paediatric and antenatal care) service points are responsible for data generation, improvement of data quality, data analysis, maintenance of patient records and registers.
		Sub-district, District and Provincial Department of Health are responsible for data analysis and quality audit.
		National Department of Health is responsible for compilation, analysis and quality audit.
The Western Cape Consolidated Guidelines for HIV Treatment: Prevention of Mother to Child Transmission of HIV (PMTCT), Children, Adolescents and Adults	2015	There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines.
Guidelines for the management of Tuberculosis, Human Immunodeficiency Virus and Sexually-Transmitted Infections in Correctional facilities	2013	Monitoring and evaluation must focus on collecting, organising and analysing data.
		It is important that the standard DOH data collection tools are used within the Department of Correction Services (DOH) including the electronic tuberculosis register (ETR.net) and the monitoring and evaluation for ART system (Tier.net).
		Duplicate data collection must be avoided and systems must aim to eliminate duplication.
		Data quality assurance processes for health data must apply to correctional centres.

Title of the guideline	Year	Extracted data management, monitoring and evaluation recommendations
		Standard tools used by the DOH will be used to monitor performance of the TB programme in DCS: TB symptom screening form, STI screening form, Facility TB treatment record (GW 20/12), Laboratory request form for Sputum Examination, Patient treatment card (GW 20/15), TB identification and follow up register (GW 20/13), Tuberculosis register (GW 20/11), Transfer/ Referral form (GW20/14) and TB Notification forms (GW17/5).
		Completeness of TB registers is vital in ensuring good quality data. The TB registers must therefore be reviewed weekly for completeness and correctness.
Managing TB in a new era of diagnostics	2016	Tools used for monitoring TB patients: TB identification and follow up register (GW 20/13), Laboratory request form for Sputum Examination, TB Patient treatment card (GW 20/15), TB treatment record (GW 20/12), Tuberculosis register (GW 20/11), Transfer form (GW20/14), TB symptom screening tool, TB patient referral form and Notification of notifiable medical condition form.
		The TB registration number must be chronologically numbered as patients present themselves.
		Facilities must analyse TB programme data on a monthly and quarterly basis.
Managing HIV, a Clinician's tool	2015	There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines.
Guidelines for the Management of HIV in Children	2010	There were no recommendations for data management, monitoring and evaluation that were identified and could be extracted from these guidelines.