University of Venda

Factors associated with maternal mortality in South Africa (2003 – 2008)

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Declaration

I, Mukondeleli Livhuwani Ellen, hereby declare that this dissertation for the Master's Degree in Statistics submitted to the department of Statistics at the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and in execution, and all reference material contained herein has been duly acknowledged.

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Supervisor:.. Date 10/10/2013..............

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Abstract

Maternal death is the death of woman during pregnancy or within 42 days of termination of pregnancy from any cause related to or aggravated by the pregnancy or its management but not from accidental or external causes. Health complications during pregnancy and child birth are a major challenge worldwide. Statistics South African reports mortality data for South Africa classified according to various demographic characteristics and causes. The causes are classified using ICD10. Using the Statistics South Africa data, this study focused on the death of a women aged between 15 to 49 over the period of 2003 to 2008.

The purpose of this study is to identify the level, trends, leading causes and factors associated with death due to maternal related causes among women aged 15-49 in South Africa and to explore the relationship between the socio-demographic and clinical factors on one hand with maternal deaths over the period 2003 to 2008. Logistic regression and log linear analysis were used to explore the relationships.

The results show that the maternal mortality ratio of South Africa increased from 114 per 100 000 live births in 2003 to 195 per 100 000 live births in 2008. Free State province had the lowest maternal mortality ratio and the Western Cape province had the highest ratio. Northern Cape had the same levels of maternal mortality as Western Cape in 2003 – 2004, but increased at a faster rate afterwads. By 2008, the rate of maternal mortality in Northern Cape was about twice that of Western Cape. The top five causes of maternal death were eclampsia (O15), puerperal sepsis (O72), postpartum hemorrhage (O85), maternal infectious and parasitic diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium (O98), other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium (O99).

There is a significant association of maternal mortality with socio demographic variables (Marital Status, Age, Death Province, Place of Death) and other illnesses (HIV, TB, pneumonia and diarrhoea). There was no significant association between maternal deaths and educational level. When four or five causes of death were listed on the death notification form, maternal mortality is not directly associated with HIV. The link to HIV is only through the opportunistic diseases associated with HIV. When only two or three causes are listed, direct association exist.

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I wish to acknowledge the financial support from NRF through Free-standing student support and work study.

Dedication

I dedicate this research to my younger brothers , sister and my daughter hluli.

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Chapter 1: Introduction

1.1 Background

Maternal health merits attention due to the threat to human existence caused by the rapid increase in the death rate of women during pregnancy, childbirth and the postpartum period (Stanton et al,1996). In order to reduce maternal mortality rate, demographers started to investigate the factors that influence maternal mortality (Illah, 2010). Maternal mortality, as part of maternal health, is a global concern affecting developed nations at a minimum level while it is more critical in developing countries.

The Centers for Disease Control (CDC) reported that there has been no improvement in the maternal death rate in the United States since 1982. This confirms that developed countries are still experiencing maternal mortality as a challenge. Rinehart et al, 1984 also confirmed that maternal mortality in developing countries has been estimated at 400 per 100,000 live births, whereas levels of maternal mortality in most of the developed world are below 25 per 100,000 live births JiaquanXu *et al*, (2010). In 2005, an estimated 536,000 women died of maternal causes worldwide of which 86% of these deaths occurred in Sub-Saharan Africa and South Asia. Less than 1% of the deaths occurred in the developed countries (WHO, 2007).

In many countries, it has been discovered that complications of pregnancy and childbirth are the leading causes of death among women of reproductive age (Romero *et al*, 2007). Roughly, a woman dies from childbirth related difficulties every day. For example, more than a thousand women are dying around the world as a result of pregnancy and childbirth related complications (Pathak, 2013). Due to the high level of maternal mortality in developing countries, one of the concerns of Millennium development goal (MDG's) is to reduce maternal mortality ratio by three quarters between 1990 and 2015 (WHO, 2010). Every year approximately 250,000 African women die during pregnancy, delivery or the puerperium. In Africa maternal mortality ratios are more than 100 times higher than those in the developed world (AbouZahr, 2003).

Measuring maternal mortality trends is the most difficult issue in maternal health because of statistical problems (WHO 2007). WHO, UNICEF and UNFPA have developed an approach to estimating maternal mortality that seeks to generate estimates for countries with no data (WHO, 2003). It is important to implement approaches to improve the maternal health. According to Ahmed and Hill (2010), methods of estimating maternal mortality are household surveys with direct death inquiry, indirect and direct sisterhood methods and reproductive age mortality surveys. The study conducted by Rao et al showed that there is no definite method of assessing the levels, pattern and causes of maternal mortality in China.

Since South Africa is a developing nation, it is also prone to high maternal mortality rate especially in rural areas. In most developing countries, data is scarce on the quantitative impact of maternal mortality because of its poor collection Zachariah *et al* (2006).

1.2 Problem statement

Maternal mortality levels remain unacceptably high in underdeveloped, developing as well as in developed countries (United Nations, 2007). According to UNICEF (2009) state of the world's children report, it was found that women in the world's least developed countries are 300 times more likely to die of childbirth or from pregnancy-related complications than women in developed countries globally, the total number of maternal deaths decreased from 543 000 in 1990 to 287 000 in 2010 (WHO, 2012). Although it looks like the trend is going down, the number of women dying of maternal related causes is still very high. In many low or middle income countries, deaths from maternal causes characterized as the leading cause of death among women of reproductive age. For example, Graham *et al* (2004) shows that the low social status of women in low income countries confines their access to economic resources and basic education, thus decreasing their ability to make decisions related to their health.

Everyday counts report (2005) in South Africa indicates that each year at least 1,600 mothers die due to complications during pregnancy and childbirth. 20,000 babies are stillborn and another 22,000 die before the age of one month. An additional 53,000 children die before their fifth birthday. This toll of over 260 deaths every day is related to 5 major challenges namely, pregnancy and childbirth complications, newborn illness, childhood illness, HIV & AIDS and malnutrition

Although South Africa's reproductive health policies and laws are among the most progressive and comprehensive in the world in terms of the recognition that they give to human rights, including sexual and reproductive rights, it is of serious concern that the current level of maternal mortality in South Africa is far higher than the MDG target of 38 per 100 000 live births by 2015. The high maternal mortality in South Africa affects families, communities and the country as a whole. It is necessary to measure the size of the problem in the various provinces of SA.

Thus, this study tries to address the leading causes of maternal mortality in South Africa, level, trends and factors associated with death due to maternal related causes. The demographic factors and clinical factors such as age, educational level, place of death, death province, marital status, TB, diarrhoea, HIV and pneumonia were used to address the problem.

1.3 Aim

The aim of this study is to identify the level, trends, leading causes and factors associated with death due to maternal related causes in SA.

1.4 Objectives of the study

The causes of death data from Statistics South Africa will be used to achieve the following objectives:

a) To establish the level and the trends in maternal mortality by use of life tables for the period 2003-2008;
b) To Identify the leading causes of maternal mortality;
c) To identify the socio-demographic factors associated with death due to maternal related causes in South Africa using logistic regression analysis;
d) To use log linear analysis in assessing death due to maternal and clinical factors in South Africa.

1.5 Research questions

In order to fulfill the objectives, the following questions were addressed:

- What are the level and trends in maternal mortality in South Africa from 2003 to 2008?
- What are the leading causes of maternal mortality in South Africa?
- What are the relationship between socio demographic factors and death due to maternal related causes South Africa?
- What are the relationship between the clinical factors (TB, HIV, pneumonia and diarrhea) and death due to maternal related causes?
- What are the factors associated with maternal mortality in SA over the period 2003 to 2008?

1.6 Significance of the study

There is a need to find out the causes of death among women during childbirth and the related socio economic factors because such information will be of utility in minimizing pregnancy related fatality. It is envisaged that the results of this study will assist policy makers for sustainable development. The investigation will also contribute immensely to our knowledge of factors (other than medical) that contribute to maternal mortality in South Africa.

Development planners will be able to channel resources to areas or provinces which are experiencing high maternal mortality rate. This will help in the formulation of policies which concern the health of women, in particular the child bearing age.

Since there are few publications about maternal mortality in the country, this study will add information to the country's database and information on maternal mortality.

1.7 Limitations of the study

Some of the analysis was not performed because of the unavailability of data. Some of the variables were mentioned below.

- Lack of completeness –variables like smoking status and occupation status, number of children of each women and number of visit when the women was pregnant were not reported. These entire variables could have helped in policy implementation.
- Late reporting – Some deaths that occurred during 2003 and 2008 were not included in the data because they did not reported in time.
- Error of coding the causes of maternal death – some of the causes of maternal death was not coded correctly for some the causes were recorded as unknown, unspecified, other and still born.
- For the period 2003, the midyear estimates of female were not grouped according to age group.
- Data period 2003 to 2008 and the analysis were based on the maternal mortality as reported by Statistics South Africa.

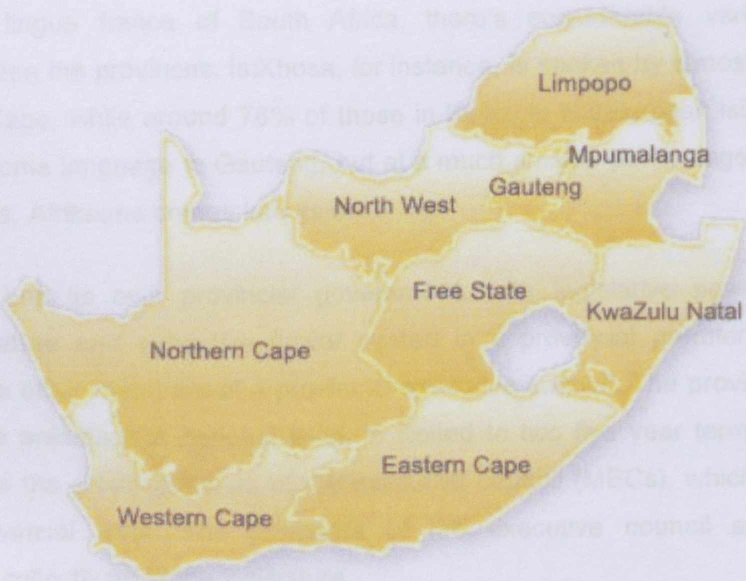

Figure 1 South Africa profile

1.9 South Africa Profile

The map in figure 1 shows the provinces in South Africa from which the the mortality data for all nine provinces in South Africa was compiled.

South Africa is one of the most ethnically diverse countries in Africa. It was inhabited by pastoral Khoekhoe (Khoi), the hunter-gatherer San, the Xhosa, and the Zulu nations and various other indigenous tribes, when Dutch settlers arrived in middle of the 17th century, much to the disadvantage of the Khoekhoe along the southern and western coastal strips.

South Africa has nine provinces, each with its own legislature, premier and executive council and distinctive landscape, population, economy and climate. Namely, Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West and Western Cape. They are vast differences in the size of the provinces, from tiny and crowded Gauteng to the vast, arid and empty Northern Cape. Mpumalanga is the second-smallest province after Gauteng; with the rest all taking between 8% and 14% of South Africa's total land area.

The number of people living in the provinces also varies considerably. Gauteng, the smallest province, has about 12, 27 million people while Northern Cape has 1, 5 million which takes up nearly a third of South Africa's land area, has by far the smallest population. Although English is the lingua franca of South Africa, there's considerable variation in home languages between the provinces. IsiXhosa, for instance, is spoken by almost 80% of people in the Eastern Cape, while around 78% of those in Kwazulu Natal speak isiZulu is also the most common home language in Gauteng, but at a much smaller percentage. In Cape Town and its surrounds, Afrikaans comes into its own.

Each province has its own provincial government, with legislative power vested in a provincial legislature and executive power vested in a provincial premier and exercised together with the other members of a provincial executive council. The provincial legislature and, as with the president at national level, is limited to two five year terms in office. The premier appoints the other members of the executive council (MECs), which functions as a cabinet at provincial level. The members of the executive council are accountable individually and collectively to the legislature.

Population density correlates with the provinces' slice of South Africa's economy, with Gauteng having the biggest. The tiny province punches way above its weight, contributing

33, 7% to the national gross domestic product in 2010 and a phenomenal 10% to the GDP of Africa as a whole. Next is Kwazulu Natal with 15, 8%, followed by the Western Cape with 14, 1%. These three provinces collectively contribute nearly two thirds to the economy.

1.10 Definition of terms and concepts

Maternal mortality: Maternal mortality is defined as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.

Maternal mortality rate: refers to the number of maternal deaths in a given period per 100000 women of reproductive age during the same period of time.

Maternal mortality ratio: Number of maternal deaths per 100,000 live births, due to complications of, or medical conditions aggravated by pregnancy, childbirth, or postnatal period up to six weeks after delivery.

Cause of death: Is the disease or injury that initiated the train of events leading to death, or the circumstances of the accident or incident that produced the fatal injury.

Age group: Is the age of women on her last birthday or interval between the date of birth and the date of census, in completed years.

Life expectancy: Is the number of years newborn children would live subject to the mortality risks, prevailing for their cross section of the population at the time of their birth, remaining constants.

Logistic regression: Is a type of predictive model that can be used when the target variable is a categorical variable with two categories.

Log linear model: Log linear analysis is an extension of the two-way contingency table where the conditional relationship between two or more discrete, categorical variables is analysed by taking the natural logarithm of the cell frequencies within contingency table.

ICD 10: The tenth revision of the International Classification of Diseases. It consists of alphanumeric designations given to every diagnosis, description of symptoms and cause of death of human beings.

1.11 List of abbreviations

MMR: Maternal Mortality Ratio

MDG: Millennium Development Goals.

WHO: World Health Organization.

ICD: International Statistical Classifications of Diseases.

SA: South Africa

SPSS: Statistical Package for the Social Sciences

HIV: Human Immunodeficiency Virus

AIDS: Acquired immune deficiency syndrome

TB: Tuberculosis.

STATSSA: Statistics South Africa

Chapter 2: Literature review

2.1 Causes of maternal mortality

Maternal mortality refers to the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental, incidental or external causes (Illah, 2010). The WHO (2013) indicates that globally, about 80% of maternal deaths are due to four major causes namely, severe bleeding, infections, hypertensive disorders in pregnancy (eclampsia) and obstructed labour.

The causes of maternal death differ among countries and regions. According to Chowdhury (2007), the major causes of maternal death internationally are due to obstetric complications, mostly haemorrhage sepsis, unsafe abortion, pre-eclampsia and eclampsia, and prolonged or obstructed labour. A study conducted in Northern Ghana shows that the direct causes of maternal mortality were hemorrhage, miscarriage, sepsis, obstructed labour, ectopic pregnancy, eclampsia and embolism while the indirect causes were malaria, HIV/AIDS, hepatitis, respiratory infections, anaemia, sickle cell disease, meningitis and cerebrovascular diseases (Mills, 2008).

A study conducted by Ramos *et al,* (2007) shows that the main causes of maternal death in Argentina were abortion complications, hemorrhage, sepsis and hypertensive disorders while in Malawi the leading causes of maternal death were postpartum hemorrhage, postpartum sepsis, and HIV/AIDS. The study by Asamoah (2011) in Ghana showed that the top five causes of maternal mortality were haemorrhage (22.8%), infectious diseases (13.9%), abortion (13.7%), miscellaneous (13.6%) and other non-infectious diseases (12.4%).

A study conducted by Jose (2010) indicates that the major causes of maternal death in Sub-Saharan Africa were hemorrhage (34%), infection (10%), hypertensive disorders (9%) and obstructed labour. In the United States, maternal mortality rate is higher among African-American women compared to those who are white, with the leading causes being hemorrhage, infection, and pre-eclampsia because African American women tend not to consult or they do not afford high medical fees (Linda and Goodrum, 2000). From the study conducted by Illa in 2010 with the main purpose of identifying the leading causes of maternal mortality in Tanzania, the results show that the main direct causes of maternal death were hemorrhage with for 28% of maternal deaths, followed by eclampsia (19%) and puerperal sepsis (8%).

According to CIA-The World Fact-book-Botswana, (1999), maternal mortality in Botswana is estimated at 200-250 maternal deaths per 100,000 live births. Studies have shown that the main causes of these deaths are hemorrhage, infections, and hypertensive disorders of pregnancy, prolonged labour, pulmonary embolism and other medical conditions.

In South Africa causes of maternal mortality have changed significantly over the years (Bradshaw and Dorrington 2012). The report on confidential enquiries into maternal deaths in South Africa, covering the period from 2005-2007 shows that the top five causes of maternal mortality are non-pregnancy related infections (43.7%), hypertension (15.7%), obstetric (antepartum plus postpartum) hemorrhage (12.4%), pregnancy- related sepsis (5.6%) and pre-existing maternal disease (6%) (Blaauw and Kekana, 2010). However, between 2008 and 2010 the top five causes of maternal mortality were direct causes (46.3%), hypertension (14.0%), obstetric hemorrhage (14.1%), pregnancy- related sepsis (5.3%) and miscarriage (3.8%).

Using 2001 data from Department of Health, Penn-Kekana and Blaauw (2002) showed that the top five causes of maternal death in South Africa were non-pregnancy related sepsis (mainly due to AIDS) 29.7%, complications of hypertension in pregnancy 22.7%, obstetric hemorrhage 13.5%, pregnancy related sepsis (includes septic abortions & puerperal sepsis) 12.4%, and pre-existing maternal disease 8.9%.

Most HIV infected women die of non-pregnancy related infections; the only other diseases which are relatively common are hypertension (5.9%), postpartum hemorrhage (4.2%) and pregnancy related sepsis (4.9%). Conversely, most of the HIV negative women die due to direct causes of death, namely hypertension (27.1%), obstetric hemorrhage (20.7%), and sepsis (8.6%) (Saving mothers, 2005-2007). Furthermore, saving mothers report showed that from 2008-2010, the five leading causes of maternal death were NPRI (40.5%), mainly deaths due to HIV infection complicated by TB, PCP and pneumonia), obstetric hemorrhage (14.1%), complications of hypertension in pregnancy (14.0%), pregnancy related sepsis (9.1%), includes septic miscarriage and puerperal sepsis) and medical and surgical disorders (8.8%). According to Nagai (2011) communicable diseases have appeared as the most common causes of death of women of reproductive age in the Agincourt sub-district at Mpumalanga, with major risk factors being increasing maternal age, complication during delivery, antenatal care visits and mother's socio-economic.

In South Africa, road accidents and injuries are important cause of morbidity and mortality in the general population with traffic accidents as an important cause of death after HIV/AIDS (South Africa report, 2003).

2.2 Effects of socio economic factors

Several factors could explain the global, country and regional decline in maternal mortality between 1990 and 2010. Furthermore, the improvement in health systems, other factors outside the health sector such as increased female education and increased physical accessibility to health facilities could be contributory factors. Given different country contexts, it is not possible to fully explain why some countries had steeper declines than others or why some made no progress (WHO 2012). The educational level, marital status, age group, place of death and province of death were also found to be very important factors in life chances and pregnancy outcomes of women and women's health generally. It was therefore concluded that the high maternal mortality can be as a result of work status, poverty, environment, health as well as violence against women (Zukang, 2010).

An analysis of maternal mortality data from Chile has found that the most important factor in reducing maternal mortality is the educational level of women. Educating women enhances women's ability to access existing health care resources, including skilled attendants for childbirth, and directly leads to a reduction in her risk of dying during pregnancy and childbirth (Melisa institute, 2012). Education can also protect girls from having children at an earlier age, with its serious consequences of premature pregnancy. Childbirth and pregnancy related deaths account for the deaths of 70000 women every year and are currently the leading causes of mortality for women aged 15-19 worldwide (Jaims, 2012).

In 2003 Statistics South Africa found that 27.5% of the population aged 20 or older had no formal school education and 41% of those in the age group 15-64 years were unemployed. According to Saffron K et al, 2011 used multi-level model to identify the relationship between maternal education and mortality among women giving birth in health care institutions. The results showed that women with no education had almost four times the risk (odds ratio 3.92: 95% confidence interval 2.60, 5.92) and those with between one and six years of education had almost twice the risk (odds ratio 1.88: 95% confidence interval 1.26, 2.79) of maternal mortality compared with women with more than 12 years of education.

Morrisson C and Jütting JP (2005) in their study indicate that people with higher levels of education are less likely to die than those without education. However, older age indicated that women were 10% less likely to experience a maternal death compared to those women less than 20 years.

Women with secondary education and above were more likely to receive antenatal care first visit, antenatal care fourth visit, seek delivery care and postnatal care by health personnel than those with no education (Paul and Rumsey, 2002). From the study conducted by Illa, 2010, the results showed that 51, 06% women had primary maternal education, 42, 55% had no maternal education while 6, 39% had post primary education. According to Asamoah *et al*, (2011) propounds that 54, 9% of maternal deaths occurred in women whose education ended at the basic level whilst 2, 1% were ascribed to those whose education ended at the tertiary and higher level.

Using multilevel analysis Karlsen *et al*, (2011) shows that in the adjusted models, women with no education had 2.7 times and those with between one and six years of education had twice the risk of maternal mortality of women with more than 12 years of education. Chowdhury *et al*, (2007) says that women with higher education may have some awareness about the effects of illness and treatment and they may have a higher demand for contraceptives and prenatal care, a higher likelihood to have a partner with higher education, and higher bargaining power at home and in their found that increases in education reduce maternal mortality.

In South Africa the effects of socio economic factors differ according the provinces of South Africa. Overall, maternal age, level of education and marital status are associated with maternal mortality (Paul and Rumsey, 2002).

2.3 Levels of maternal mortality

The extent of the problem of maternal mortality and the trend over previous years are needed for planning monitoring and evaluating programmes. Measurement of the level of maternal mortality is difficult because of incompleteness of death registrations (WHO, 2007). The most commonly used indicator of maternal mortality is the maternal mortality ratio. It is computed as the number of maternal deaths during given the time period per 100 000 live births during the same year. The maternal mortality ratio is usually computed at the national level and rarely at sub-national level.

Hogan and Foreman (2010) assessed levels and trends in maternal mortality for 181 countries in their report titled maternal mortality for 181 countries, 1980 to 2008 a systematic analysis of progress towards Millennium Development Goal 5. They constructed a database of 2651 observations of maternal mortality for 181 countries for 1980 to 2008, from vital registration data, censuses, surveys, and verbal autopsy studies. They used robust analytical methods to generate estimates of maternal deaths and the MMR for each year between 1980 and 2008. They explored the sensitivity of the data to model specification and show the out-of-sample predictive validity of the methods. As a result, they estimated that there were 342 900 maternal deaths worldwide in 2008 down from 526 300 in 1980. The global MMR decreased from 422 in 1980 to 320 in 1990 and was 251 per 100 000 live births in 2008. The yearly rate of decline of the global MMR since 1990 was 1·3%. They found out that in the absence of HIV there would have been 281 500 maternal deaths worldwide in 2008. The report concluded that although substantial progress has been made towards MDG 5, only 23 countries are on track to achieving a 75% decrease in MMR by 2015 and that countries such as Egypt, China, Ecuador, and Bolivia have been achieving accelerated progress.

In developed countries maternal mortality range from 5.4 to 12 per 100 000 live births while middle income countries such as Mexico report a rate of 106 per 100 000 live births. In Africa the maternal mortality ratio is estimated to range from 424 to 2151 per 100 000 live births.

According to Statistics South Africa (STATSSA) report about MDGs country, they indicated that there is an increased trend of MMR estimates in SA from 1997 (80.7) to 2002 (123.7) per 100 000 (Statssa, 2005). Based on the 1998 South Africa Demographic and health Surveys the MMR in SA was 150 per 100 000 live births for the approximate period of 1992-1998. According to Black et al (2009) states that the maternal mortality ratio at Charlotte Maxeke Johannesburg hospital from 2003 to 2007 was 289 per 100 000. In South Africa the maternal mortality ratio was estimated to be 570 per 100 000 live births. However, the raw estimate of maternal mortality was 702 per 100,000 live births, a value higher than any other estimate for South Africa (Dorrington et al, 2001).

2.4 Statistical methods

This section briefly discusses all the statistical methods that will be used to analyses the data namely, logistic regression analysis and log linear analysis.

2.4.1 Logistic regression

Logistic regression is a form of statistically modelling that is often appropriate for categorical outcome variables. It may be described as an optimal method for the regression analysis of dichotomous (binary) dependent variables. It allows the multiple predictor variables, which can be continuous, nominal or ordinal categorical variables. It can provide estimates of adjusted odds ratio (Garson, 2009). Since the binary variables are coded as 0 and 1. Then the mean of the regression model is the probability of success in the distribution which is written in this form:

$\theta(x) = P(y=1)$

The logistic regression function is the transformation of θ and is given in the form of:

$$\theta(x) = \frac{e^{p(x)}}{1-e^{p(x)}},$$

Where $\theta(x) = P(Y \text{ given } x)$ is the quantity representing the conditional mean of Y given x

The value of Y is assumed to be 1 or 0 and the values of x are to be defined. In logistic regression model $\theta(x) = P(Y = 1 | x)$ and $P(x)$ is the logistic transformation of $\theta(x)$ defined as

$$P(x) = log\left(\frac{\theta(x)}{1-\theta(x)}\right) = \alpha + \beta x$$

Therefore the logistic regression equation is defined as; $P(x) = \frac{e^{\alpha+\beta x}}{1-e^{\alpha+\beta x}}$

Where

$\theta(x)$ = probability of the outcome

α = is the constant of the equation

β = Is the coefficient of the predictor variables

x = is the predictor variable

The graph of the logistic function is *S*-shaped and is bounded at zero and one (figure 2), so impossible predictions cannot occur. In logistic regression, the relationship between a quantitate binary respond y and the predictor is curvilinear. The pattern of one particular curvilinear that is common, is the S-shape and is represented below,

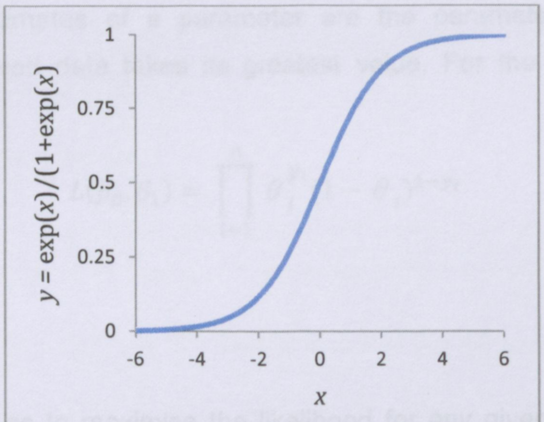

Figure 2 Logistic curve

This curve can be obtained from the formula defined as,

$$P = \frac{e^{a+bx}}{1+e^{-(a+bx)}}$$

$$= \frac{1}{1+e^{-(a+bx)}}$$

Where,

P is the probability of a 1 and a, b are the coefficients that determine the logistic intercepts and slope, and e is the base of the natural log function.

Due to the nature of exponential function the value of – (a+bx) should be computed on a small range of real numbers. There are important points that one need take note of when the values of a and b changes. Now since the relationship between P and x is nonlinear, the slope will vary as x varies. If P is obtained as 0.5, the slope will be b divided by 4, in case like these a and b will have the same qualitative effects on the logistic regression. When the value of an increases, then the overall value of P will increase. And if b increases then the degree to which P increases will increase as x increase. The S- shape curve is obtained if the values of – (a+bx) ranges from negative infinity to positive infinity. This logistic function can be applied in different fields such as biology, chemistry, demography, economics, sociology and statistics to model the relationship between independent and dependent variables (http//luna.cas.usf.edu/~mbrannic/files/regression/Logistic.html, accessed on 13 june 2012)

Parameter estimates

The parameters in the model can be estimated using method of maximum likelihood. The maximum likelihood estimates of a parameter are the parameter value for which the probability of the observed data takes its greatest value. For the logistic regression, the likelihood function is

$$L(\beta_0, \beta_1) = \prod_{i=1}^{n} \theta_{i}^{y_i}(1-\theta_{i})^{1-y_i}$$

With $\theta_i = \dfrac{e^{\beta_0+\beta_1 x_i}}{1+e^{\beta_0+\beta_1 x_i}}$.

Now, choose β_0 and β_1 as to maximise the likelihood for any given data, for simple linear regression minimizing the sum of squared residuals is equivalent to maximizing normal distribution likelihood.

The logit transformation is developed by considering the equation

$$\theta = \frac{e^{\beta_0+\beta_1 x}}{1+e^{\beta_0+\beta_1 x}}$$

From which we get

$$\frac{\theta}{1-\theta} = e^{\beta_0+\beta_1 x}$$

Thus, the logistic regression model can be expressed alternatively as

$$\text{Logit}(\theta) = \ell n\left(\frac{\theta}{1-\theta}\right) = \beta_0 + \beta_1 x.$$

So that the equation models the odds as a linear function of x.

Having estimated the parameters β_0 and β_1 as b_0 and b_1 respectively, the estimate of by using the back-transformation,

$$\hat{\theta} = \frac{e^{b_0+b_1x}}{1+e^{b_0+b_1x}}.$$

Goodness of fit

A statistical model must be evaluated to determine how well it fits the data. For the logistic regression model, the goodness of fit can be measured by G statistic, Pearson statistic, Hosmer-Lemeshow statistic or the Wald statistic. In this study, the goodness of fit for the models is evaluated by the G statistic, and the significance of individual predictors will be determined using the Wald statistic.

The G^2 statistic is geneally defined as

$$G^2 = -2log\left[\frac{maximum\ likelihood\ when\ parameter\ satisfy\ Ho}{maximum\ of\ the\ likelihood\ when\ parameters\ are\ unrestricted}\right]$$

For the binary logistic regression, the G^2 statistic is called the deviance, and reduces to:

$$D = 2\sum_{i=1}^{n} y_i \ln\left(\frac{\theta(x_i)}{y_i}\right) + (1-y_i)\ln\left(\frac{1-\theta(x_i)}{1-y_i}\right)$$

To determine the overall significance for a model using the G statistic, the deviance for the model and the deviance for the intercept-only model are subtracted. The larger the difference, the greater the evidence that the model is significant. Under the null hypothesis that the model is true, the G statistic follows a chi-squared distribution with $p - 1$ degrees of freedom, where p is the number of parameters in the model.

The Wald test statistic is commonly used to test the significance of individual logistic regression coefficients for each independent variable.
For a predictor variable with parameter β_j, which is estimated by $\hat{\beta}_j$, the Wald Statistic is

$$W = \left[\frac{\hat{\beta}_j - \beta_j}{st.\,error(\hat{\beta}_j)}\right]^2.$$

If β_j is the true value of the coefficient, then *W* has a chi-square distribution (approximately, when the sample size is large enough) (Garson, 2009).

Assumptions of logistic regression analysis

- The independent variables be interval, ratio, or dichotomous.
- All relevant predictors be included, no irrelevant predictors be included, and the form of relationship is linear:
- There is no autocorrelation
- There is no correlation between the error and the independent variables;
- There is an absence of perfect multi linearity between the independent variables (Hosmer and Lemeshow, 2000).

2.4.2 Log linear analysis

The log linear model is a special case of generalized linear models for Poisson-distributed data. Log linear analysis is an extension of the two-way contingency table where the conditional relationship between two or more discrete, categorical variables is analyzed by taking the natural logarithm of the cell frequencies within a contingency table (Mubrooka, internet). Log linear model is appropriate when there is no clear distinction between response and explanatory variables.

The basic strategy in log linear modeling involves fitting models to the observed frequencies in the cross-tabulation of categorical variables. The models can then be represented by a set of expected frequencies that may or may not resemble the observed frequencies. The dimension of a log linear model is determined by the number of variables being considered. A model to compare *k* variables is *k*-dimensional.

Log-linear models are described in terms of the constraints they place on the associations or interactions that are present in the data. The pattern of association among variables can be described by a set of odds and by one or more odds ratios derived from them. The complexity of a model is the degree of interaction that exist. The simplest model is one in which there is no interactions between/among the variables, and is usually referred to as the complete independent model. On the other hand, a model that includes all possible interactions among the variables is called a saturated model. A saturated model does not provide any simplified description of the relationship that exist among the variables being analyzed (Anil internet)

A hierarchy of models exist whenever a complex multivariate relationship present in the model necessitates inclusion of less complex interrelationships. Thus, a hierarchy exists between two specified models if all parameters present in the simpler model can also be found in the more complex model of the other. Two log-linear models can be compared if a hierarchical relation exists between them.

For a log-linear model involving three variables (*X*, *Y* and *Z*), let μ_{ijk} represent the expected count for level *i* of *X*, level *j* of *Y* and level *k* of variable *Z*. Then a saturated log-linear model that describes the relationships among the variables is specified as

$$\log(\mu_{ijk}) = \mu + \lambda_i^{X} + \lambda_j^{Y} + \lambda_k^{Z} + \lambda_{ij}^{XY} + \lambda_{ik}^{XZ} + \lambda_{jk}^{YZ} + \lambda_{ijk}^{XYZ}.$$

Different models will impose constraints on the parameters. For example a model of complete independence among the three variables implies that all interaction terms are set to zero, and we are left with the reduced model

$$\log(\mu_{ijk}) = \mu + \lambda_i^{X} + \lambda_j^{Y} + \lambda_k^{Z}.$$

An analysis of the model requires that the parameters of the model be estimated from the data, from which the expected cell counts are computed. If a series of hierarchical models are specified, and expected frequencies are obtained for each model, then we can compare and choose a preferred model, which is the most parsimonious model that fits the data. The choice of a preferred model is typically based on a formal comparison of goodness-of-fit statistics associated with models that are related hierarchically (models containing higher order terms also implicitly include all lower order terms). Ultimately, the preferred model should distinguish between the pattern of the variables in the data and sampling variability, thus providing a defensible interpretation. (Agresti, 2007).

There are two stepwise approaches that one can take in order to choose the best model:

a. Start with the saturated model and begin to delete higher order interaction terms until the fit of the model to the data becomes unacceptable based on the probability standards adopted by the investigator.

b. Start with the simplest model (independence model) and add more complex interaction terms until an acceptable fit is obtained which cannot be significantly improved by adding further terms (Jeansonne, internet).

The parameters are estimated by the method of maximum likelihood. For certain models, closed-form solutions to the likelihood equations exist. When a closed form solution does not exist, numerical methods are used to estimate the model parameters, from which the expected cell counts are obtained (Knoke and Burke, 1980).

The degree to which a model fits the data is measured by the use of Goodness of Fit statistics. The two statistics used for this purpose are the Likelihood Ratio chi square (G^2), or the Pearson chi square. The G^2 is preferred because parameter estimates are obtained by maximum likelihood and this statistics can also be used to compare two hierarchical models while the Pearson statistic cannot be used for this purpose. A model fits the data well if the estimated expected cell counts computed using the model is close to the observed cell counts. The degree to which the estimated expected cell counts are close to the observed cell counts is measured by the goodness of fit statistics. The smaller the value of the statistic the better the fit of the model.

Log linear modeling and logistic regression modeling are both specific examples of generalized linear modeling. The two procedures differ in three ways:

- In log linear analysis, the expected distribution of the categorical variables is Poisson, not binomial or multinomial as in logistic regression.
- The link function is the natural log of the response under log linear, not the logit of the response variable as in logistic regression.
- For log linear predictions are estimates of the cell counts in a contingency table, not the logit of the expected value of a Bernoulli variable.

Chapter 3: Methodology

3.1 Introduction

This chapter describes the statistical procedures used in order to achieve the objectives already set out, namely, logistic regression and log linear analysis.

3.2 Data source

Two important data sets were used for this project. The "Causes of Death from Death Notifications" data set and the Live Births data set, both provided by STATSSA. The data covers all the nine provinces of South Africa from 2003 to 2008. Mortality data was extracted from death notification forms provided to STATSSA by the Department of Home Affairs. The first page of the form contains the full particulars of the deceased, particulars of the informant, and certification of the cause of death by the attending medical professional. The other page contains the demographic information such as: sex, age, population group, date of birth, marital status, level of education, occupation, place of death, smoking habits and pregnancy status. In addition to an immediate cause of death, up to four additional causes contributing to death may be listed on the death notification. From the maximum of five multiple causes of death listed, an underlying cause of death is identified and captured in the database. All the causes were classified using the International Classification of Diseases (ICD 10). ICD 10 provides a uniform method classifying all diseases using a system of letters and numbers. The Live Births data for each year (2003-2008) is provided in tabular form, showing the age of the mother and the province of birth. Midyear population estimates by age group and province were also provided by STATSSA for the years covered in this study.

This study focuses on the deaths of women aged between 15 and 49, where the deaths are related to maternal causes. ICD-10 classifies maternal deaths with codes O00 to O99.

3.3 Data Analysis

Descriptive statistics such as the crude death rate and the maternal mortality ratio will be used to shed light on mortality and causes of death among women aged 15 to 49 years of age in South Africa over the period 2003 to 2008. Frequency counts will be used to identify the leading causes of maternal deaths. Three situations are identified for maternal deaths (coded O00 to O99 of ICD-10):

- Immediate cause of death (Cause A) is maternal
- Underlying cause of Death is maternal
- Contributing cause of death (Cause A – Cause E) is maternal

The crude death rate is defined as the average number of deaths in a year per 100 000 population, while the maternal mortality ratio is defined as the average number of maternal deaths in a year per 100 000 live births in the year. Crude death rates and maternal mortality rates will be computed for each province and for each age group. The results will be graphed in order to illustrate the trend in these rates over time for each age group and for each province

A binary dependent variable *Y* will be created, denoting whether or not a particular death was due to maternal causes or not. A death is deemed to a maternal death if any of the five causes (immediate or contributing causes identified as CauseA, CauseB, CauseC, CauseD and OtherCause) is coded as O (O00 to O99). This binary dependent variable will be used in the binary logistic regression analysis which is performed to determine the association of maternal deaths with the demographic and clinical predictor variables. The demographic independent variables are

- Age
- Educational level
- Marital status
- Place of death
- Province of death.

The binary clinical predictor variables are

- TB
- HIV
- Pneumonia,
- Diarrhoea

These clinical variables denote whether or not each of the disease mentioned as one of the causes of death or not. These causes of death were chosen in order to investigate the relationship of maternal deaths to HIV and its associated opportunistic infections. The variables coding are as follows:

- **Dependent variables**

The dependent variables were coded as:

$$Y = \begin{cases} 1, & \text{if death is due to a maternal cause} \\ 2, & \text{If death is not due to a maternal cause.} \end{cases}$$

- **Independent variables**

The independent variables were coded as:

$$X_1 = \text{Age group} = \begin{cases} 1, & 15-19 \\ 2, & 20-24 \\ 3, & 25-29 \\ 4, & 30-34 \\ 5, & 35-39 \\ 6, & 40-44 \\ 7, & 45-49 \end{cases}$$

$$X_2 = \text{Educational level} = \begin{cases} 1 & \text{None} \\ 2 & \text{Secondary} \\ 3 & \text{Tertiary} \\ 4 & \text{Unspecified} \end{cases}$$

$$X_3 = \text{Marital status} = \begin{cases} 1 & \text{Single} \\ 2 & \text{Married} \\ 3 & \text{Widowed} \\ 4 & \text{Divorced} \\ 5 & \text{Unspecified} \end{cases}$$

$$X_4 = \text{Province of death} = \begin{cases} 1 & \text{Limpopo} \\ 2 & \text{Eastern Cape} \\ 3 & \text{Northren Cape} \\ 4 & \text{Free state} \\ 5 & \text{KwazuluNatal} \\ 6 & \text{North west} \\ 7 & \text{Gaunteng} \\ 8 & \text{Mpumalanga} \\ 9 & \text{Western Cape} \end{cases}$$

$$X_5 = \text{Place of death} = \begin{cases} 1 & \text{Hospital} \\ 2 & \text{Emergency} \\ 3 & \text{Dead on Arrival} \\ 4 & \text{Other} \\ 5 & \text{Unspecified} \end{cases}$$

$$X_6 = \text{HIV} = \begin{cases} 1 & \text{HIV is mentioned as a cause of death} \\ 2 & \text{HIV is not mentioned as a cause of death} \end{cases}$$

$$X_7 = \text{TB} = \begin{cases} 1 & \text{TB is mentioned as a cause of death} \\ 2 & \text{TB is not mentioned as a cause of death} \end{cases}$$

$$X_8 = \text{Pneumonia} = \begin{cases} 1 & \text{Pneumonia is mentioned as a cause of death} \\ 2 & \text{Pneumonia is not mentioned as a cause of death} \end{cases}$$

$$X_9 = \text{Diarrheoa} = \begin{cases} 1 & \text{Diarrhoea is mentioned as a cause of death} \\ 2 & \text{Diarrhoea is not mentioned as a cause of death} \end{cases}$$

3.3.1 Logistic regression model

In this study the logistic procedure will be used for modeling the probability that death is due to a maternal related cause, given demographic and clinical variables. The logistic model used is given by:

$$Y_i = \text{logit}(\pi_i) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \beta_7 x_{7i} + \beta_8 x_{8i} + \beta_9 x_{9i},$$

Where π_i is the probability that one of the causes of death of individual number *i* was maternal related, and the dependent and independent variables are as defined above.

The binary logistic regression procedure in SPSS is used to fit the logistic regression model. The logistic procedure requires all data cases to be complete and estimate the coefficients of the linear predictor and their standard error estimate, the fitted probabilities, confidence limits and the regression diagnostic statistics, for any observation with non-missing explanatory variable values.

The goodness of fit of a statistical model describes how well the model fits a set of observations. Measures of goodness of fit typically summarize the discrepancy between observed values and the values expected under the model in question. Some of the available statistics for determining the goodness of fit of a logistic regression are described below.

- **Pearson and deviance goodness of fit statistic**

The Pearson statistic is based on traditional chi-square for categorical variables and the deviance statistic is based on likelihood ratio chi-square. The deviance test is preferred over the Pearson. Pearson and chi-square test indicate whether there is a relationship between the dependent and independent variables.

- **Hosmer and Lemeshow Statistic**

This is a statistical measure that tells how good the model is. This test divides subjects into deciles based on predicted probabilities and then computes a chi square from observed and expected frequencies.

- **The likelihood ratio Statistic**

Likelihood ratio test is a statistical test used to compare the fit of two models, one of which (the null model) is a special case of the other (the alternative model). The test is based on the likelihood ratio, which expresses how many times more likely the data are under one model than the other. This likelihood ratio, or equivalently its logarithm, can then be used to compute a p-value, or compared to a critical value to decide whether to reject the null model in favor of the alternative mode. When the logarithm of the likelihood ratio is used, the statistic is known as a log-likelihood ratio statistic, and the large sample probability distribution of this test statistic, assuming that the null model is true, is the chi-square.

- **Classification tables**

Classification tables are 2 × 2 tables provided in the logistic regression output for binary dependent variables. The table is used to summarize the results of fitted logistic regression model. This table is derived from the results of the cross classifying the outcome variable *Y* with a dichotomous variable whose values are derived from the estimated logistic probabilities. In the table, the columns represent the predicted values of the dependent and the rows are the observed value of the dependent variable. For a perfect model, all cases will be on the diagonal and the overall correct percentage will be 100%.

- **Cox & Snell and Nagelkerke's R^2**

The Cox and Snell statistic attempts to copy the interpretation of multiple R square in ordinary least squares regression, based on the log likelihood of the final model against the log likelihood for the baseline model. Nagelkerke's R^2 is a modification of the Cox and Snell coefficient to assure that its values range from 0 to 1. This is done by dividing the Cox and the Snell's R^2 by its maximum, so that a measure that ranges from 0 to 1 is being achieved.

3.3.2 Log linear model

The use of log-linear modeling has been recommended as a second statistical analysis method when the dependent and independent variables are categorical in nature. A unique feature of log-linear analysis is its ability to capture the interrelationships among the responses of subjects and the factorial structure of the study design categories. A log-linear model describes the association and interaction patterns among a set of categorical variables.

The model was fitted using a saturated model. The saturated model in log-linear analysis is a kind of model that incorporates all the possible effects, such as one-way effect, two-way interactions effect, three-way interactions, etc. A saturated model imposes no constraints on the data and always reproduces the observed cell frequencies. The parsimonious models in log-linear analysis is an incomplete models that somehow achieve a satisfactory level of goodness of fit.

In this study, the log-linear model is applied to explore the inter-relationship of maternal deaths due to HIV and its associated opportunistic infections. The binary variables defined earlier will be used:

Maternal Death (MT), HIV, TB, Pneumonia (PN) and Diarrhea (DR)

A unique problem arises, in that not every observation in the data set has five causes of death listed. Several observations have only an immediate cause of death listed. For these cases, a log-linear model comparing different causes of death is not possible. When only two causes of death are listed, maternal deaths can be compared against only one other cause of death. Similarly, MT can only be compared against two other causes of death if only three causes of death are listed. Thus, the log linear modeling performed will depend on the number of causes of death listed.

When four causes are listed, then only four of the variables of interest can be investigated at a time. Keeping MT in all models, the following sets of variables can be considered

- MT, HIV, TB, and PN
- MT, HIV, TB, and DR
- MT, PN, DR, and TB
- MT, HIV, PN and DR

When three causes are listed, then only three of the variables of interest can be investigated at a time. Keeping MT in all models, the following sets of variables can be considered:

- MT, HIV and TB
- MT, HIV and PN
- MT, HIV and DR
- MT, TB, and PN
- MT, TB, and DR

When two causes are listed, then only two of the variables of interest can be investigated at a time. Keeping MT in all models, the following sets of variables can be considered:

- MT, HIV
- MT, PN
- MT, HIV
- MT, DR

The backwards elimination procedure will be used to determine the most parsimonious model that fits the data. To do this, only hierarchical models will be considered. A log linear model is hierarchical if, for each higher order term in the model, all lower order terms including main effects involving the same variables must also stay in the model. Thus, the best model is defined by the set of highest order terms, which together are referred to as the generating class. The generating class describes the most complex interactions among the classification variables.

It is important to make a decision about which particular model provides the best fit after fitting a series of models. The likelihood ratio statistic, G^2, is important for comparing any two log linear models that are nested (Bishop *et al*, 2007). When the models are nested, and both fit the data according to the G^2 criterion, they are compared using a chi-square difference test. The chi-square difference statistic is computed by subtracting the likelihood ratio chi-square statistics (G^2) for the two models being compared. The value is then compared to the chi-square critical value at their difference in degrees of freedom. If the chi-square difference is smaller than the chi-square critical value, the model with fewer terms fits the data just as well as the model with more terms. The smaller the model is then the preferred model better and is the preferred model. Otherwise, if the chi-square difference is larger than the critical value, the extra terms in the larger model represents a significant improvement in the fit and is preferred.

Chapter 4: Analysis and interpretation

4.1 Descriptive Statistics and trend analysis

Table 1 Socio demographic factors of women between 15-49 years who died between 2003 and 2008

Demographic factors	Frequency	Percent
Age group		
15-19	26337	3.3
20-24	84537	10.4
25-29	153432	18.9
30-34	175383	21.6
35-39	147711	18.2
40-44	122449	15.1
45-49	100498	12.4
Total	810347	100
Marital status		
Single	513525	63.4
Married	135228	16.7
Widowed	16265	2.0
Divorced	8266	1.0
Unknown	2149	0.3
Unspecified	134914	16.6
Total	810347	100
Educational level		
None	34709	4.3
Primary	127446	15.7
Secondary	209881	25.9
Tertiary	10622	1.3
Unknown	1738	0.2
Unspecified	425951	52.6
Total	810347	100
Place of death		
Hospital (in-patient)	376488	46.5
Emergency room/out-patient	13558	1.7
Dead on arrival	15938	2.0
Nursing home	9926	1.2
Home	262104	32.3
Other	22497	2.8
Unknown	1761	0.2
Unspecified	108075	13.3
Total	810347	100

From table 1, there were a total of 810347 women who died at the age of 15-49 in South Africa from 2003 to 2008. The results show that the highest proportion of deaths occurred at the age group of 30-34 with 21.6%. The lowest proportion occurred at the age group (15-19) with 3.3% followed by age group 45-49 with 12.4%. On marital status, more than 50% women who died among 15-49 years were single while less than 5% were widowed, divorced and unknown. In terms of educational level, 25, 9% had secondary education while those with tertiary education had only 1.3%. From all the deaths that occurred from 2003 to 2008, majority of women died at the hospital with 46.5% followed by those who died at home with 32.3%. The lowest proportion occurred to those who died but not specify the place of death with 0.2% followed by those who died at the nursing home with 1.2% at the emergency room with 1.7%.

Table 2 Distribution of deaths of women aged 15 to 49 years that are due to maternal causes and non-maternal causes in South Africa over the period 2003 to 2008

Year	Number of Maternal Deaths	Number of non-maternal deaths	Total
2003	1030	126123	127153
2004	1203	136656	137859
2005	1306	139451	140757
2006	1448	139348	140796
2007	1922	132751	134673
2008	2059	127050	129109
Total	8968	801379	810347

Table 2 above shows the distribution of the deaths due to maternal causes and non-maternal causes of women aged 15 to 49 in South Africa over the period 2003 to 2008. The results showed that out of 810347 women who died 8968 died as a results of maternal causes while 801379 died as a result of non-maternal causes. The results show the increasing trend of deaths due to maternal causes from 2003 to 2008.

Table 3 Distribution of deaths of women aged 15 to 49 years by causes of death

Year	Number of deaths	Immediate cause is maternal		Underlying cause is maternal		Contributing cause is maternal	
		N	%	N	%	N	%
2003	127153	770	60.56%	894	70.31%	1030	81.00%
2004	137859	1171	84.94%	1150	83.42%	1203	87.26%
2005	140757	1272	90.37%	1239	88.02%	1306	92.78%
2006	140796	1415	100.50%	1370	97.30%	1448	102.84%
2007	134673	1815	134.77%	1747	129.72%	1922	142.72%
2008	129109	1903	147.39%	1779	137.79%	2059	159.48%
Total	810347	8346	102.99%	8179	100.93%	8968	110.67%

The table above shows the distribution of causes when maternal was listed as a cause (O00-O99) by year, the results indicated that out of 810347 women who died from 2003 to 2008 in South Africa, 8346 (102.99%) died as a result of immediate causes, 8179 (100.93%) died as a result of underlying causes while 8968 (110.67%) died when maternal was listed as the contributing cause. Therefore from all the causes there is an increase trend since 2003 to 2008.

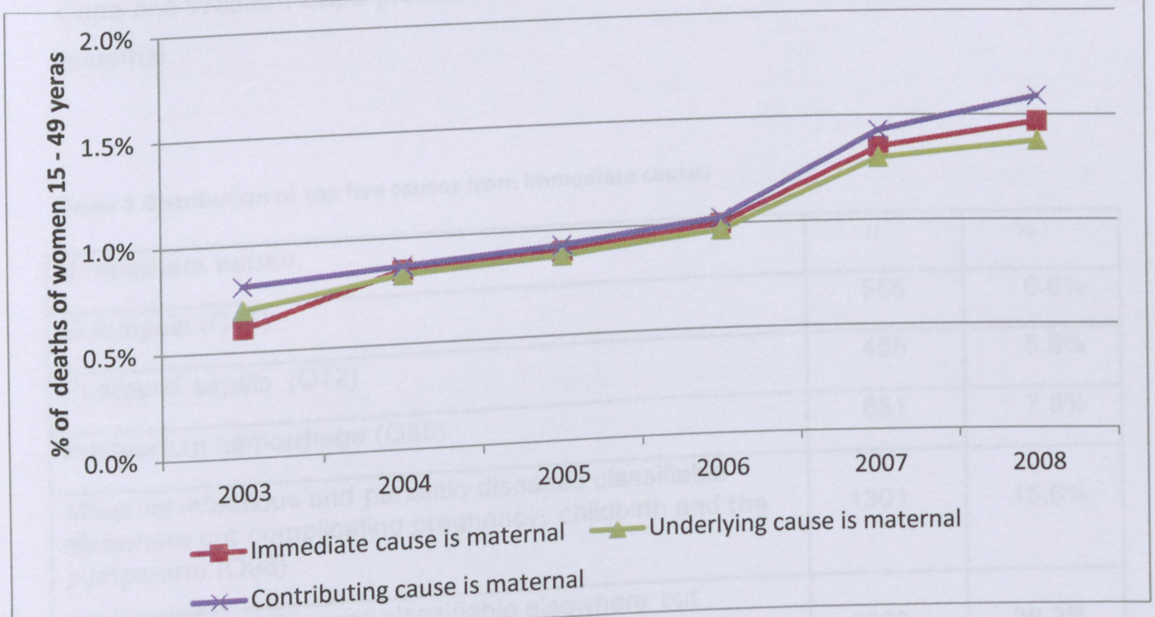

Figure 3 Trends in maternal deaths from 2003 to 2008

Table 4 Distribution of deaths by and causes of death per province

Province	Number of Deaths	Immediate cause is maternal		Underlying cause is maternal		Contributing cause is maternal	
		N	%	N	%	N	%
Western Cape	68319	340	49.77	310	45.38	388	56.79
Eastern Cape	123114	1252	101.69	1241	100.80	1358	110.30
Northern Cape	16124	137	84.97	137	84.97	151	93.65
Free State	75133	767	102.09	777	103.42	828	110.20
KwaZulu-Natal	212215	1976	93.11	1887	88.92	2122	99.99
North West	68585	683	99.58	686	100.02	727	106.00
Gauteng	138868	1614	116.23	1572	113.20	1718	123.71
Mpumalanga	70997	814	114.65	804	113.24	860	121.13
Limpopo	36992	763	206.26	765	206.80	834	225.45

Table 4 shows the distribution of deaths of women and causes of deaths per provinces of SA. The provinces with the highest cases of maternal deaths, as a proportion of all deaths of women between the ages of 15 and 49 are Gauteng, Mpumalanga and Limpopo. Northern Cape and Western Cape provinces have the lowest proportions of deaths being classified as maternal.

Table 5 Distribution of top five causes from immediate causes

Immediate cause	*n*	%
Eclampsia (O15)	555	6.6%
Puerperal sepsis (O72)	455	5.5%
Postpartum hemorrhage (O85)	651	7.8%
Maternal infectious and parasitic diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium (O98)	1301	15.6%
Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium (O99)	3268	39.2%

Over the period 2003 to 2008, there were 8346 women whose immediate cause of deaths was classified as maternal related. Cumulatively, the top 5 leading maternal causes of death account for 6230 (74.5%) of all maternal deaths (See table 5 and figure 4). The fact that most of the deaths were not autopsied is reflected in the classification of O98 and O99 (Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium). This classification seems to indicate that the immediate cause of death was maternal, but the specific maternal cause was not identified.

Table 6 Distribution of top five causes from underlying cause

Underlying cause	n	%
Eclampsia (O15)	907	11.1%
Puerperal sepsis (O72)	609	7.5%
Postpartum hemorrhage (O85)	804	9.8%
Maternal infectious and parasitic diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium (O98)	1129	13.8%
Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth and the puerperium (O99) with each independent variables	1304	15.9%

The underlying causes of death identified from the multiple causes of death on the death notification forms, the top five underlying causes of maternal deaths are extracted and displayed in table 6 and figure 5. Out of the deaths recorded, 8179 were identified as having an underlying cause that is maternal. About 30% of all the maternal underlying causes of death were not precisely defined (ICD-10 classification as O98 and O99)

Table 7 Distribution of leading immediate causes of maternal mortality by demographic variables

Age group	O98	O72	O15	O99	O85	All deaths
15-19	69	39	110	291	61	26337
20-24	277	77	133	659	160	84537
25-29	398	86	105	866	177	153432
30-34	345	111	118	776	134	175383
35-39	156	90	62	474	93	147711
40-44	42	45	24	169	22	122449
45-49	14	7	3	33	4	100498
Total	1301	455	555	3268	651	810347
Marital status						
Single	944	259	377	2094	452	513525
Married	166	131	110	633	104	135228
Widowed	10	4	6	20	6	16265
Divorced	2	2	1	5	3	8266
Unknown	4	6	3	10	3	2149
Unspecified	175	53	58	506	83	134914
Total	1301	455	555	3268	651	810347
Educational level						
None	34	17	20	81	18	34709
Primary	154	79	64	405	105	127446
Secondary	418	140	188	989	213	209881
Tertiary	13	9	6	78	3	10622
unknown	5	0	0	8	2	1738
Unspecified	677	210	277	1707	310	425951
Total	1301	455	555	3268	651	810347
Place of deaths						
Hospital (in-patient)	1061	290	372	2476	450	376488
Emergency room/out-patient	13	9	16	63	8	13558
Dead on arrival	15	11	19	46	8	15938
Nursing home	6	2	0	7	0	9926
Home	97	74	67	303	137	262104
Other	10	13	18	48	4	22497
Unknown	2	1	1	3	0	1761
Unspecified	97	55	62	322	44	108075
Total	1301	455	555	3268	651	810347

In all the causes of maternal mortality as seen in table 7, maternal mortality was generally high for women aged 26 to 34 compared to other age groups. Single women tend to die from maternal causes more than married, divorced or widowed women. Generally, most of these women tend to have tertiary education, though for a substantial number of cases, educational level was unknown. The deaths tend to occur at hospitals or nursing homes.

Table 8 Distribution of the crude deaths rate per 100 000, midyear population and the number of deaths of all women aged 15-49 from 2003-2008.

Year	Midyear Population estimate (15 – 49 yrs.)	Number of Deaths of women 15 – 49 years	Crude death Rate per 100000 population
2003	13247406	127215	960.3
2004	12644218	138023	1091.6
2005	12538000	140814	1123.1
2006	12676200	140859	1111.2
2007	12783900	134793	1054.4
2008	13464600	129109	958.9

Table 8 shows the midyear population of woman aged 15 to 49, number of women who died and the crude deaths rate per 100 000 from 2003 to 2008. Results depicted by table 8 indicates an increase of midyear estimates every year while there is a fluctuation in the number of deaths and the crude deaths rates from 2003 to 2008.

Table 9 Age-specific death rate by year by age group

Year	15-19	20-24	25-29	30-34	35-39	40-44	45-49
2003	169	627	1219.9	1553.8	1299.3	1222.8	1175.2
2004	186	640.1	1285	1638.2	1708.2	1545.5	1387
2005	182.9	638.7	1299.6	1641.1	1824.1	1635.6	1479
2006	184.7	629.4	1227.3	1605	1780.3	1702.8	1528.2
2007	167.6	585.7	1144.6	1516.5	1635.4	1680	1517.5
2008	159.6	530.4	1041.6	1340.8	1433.1	1536.9	1416.6

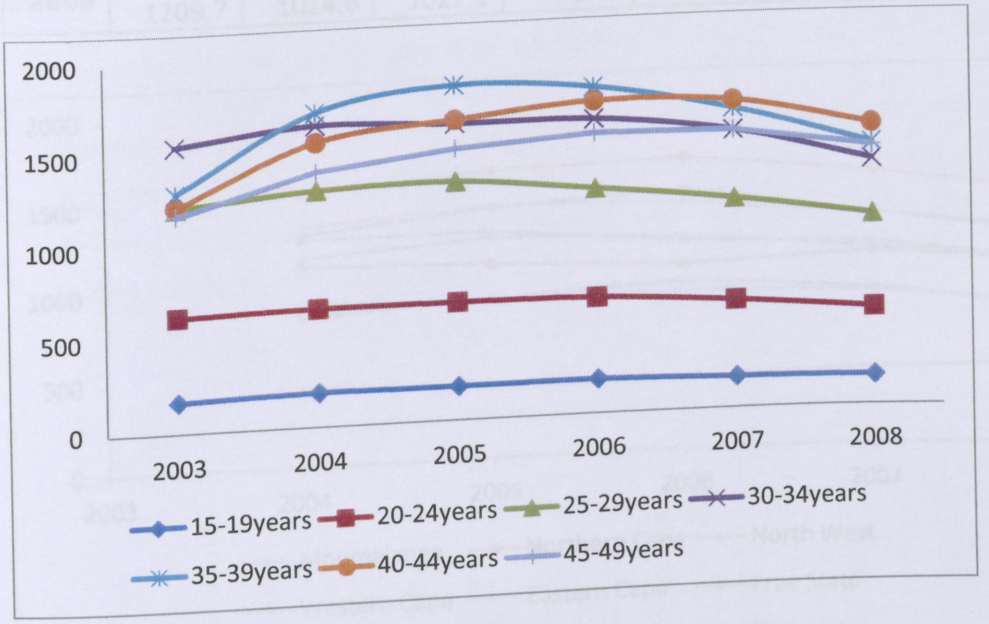

Figure 4 Age-specific maternal death rates by year and by age group

Age specific death rates are computed for five-year age groups as displayed in table 9 and figure 6 above. From age 25 onwards, the age specific death rate per 100 000 population is over one thousand. The crude death rates generally show a fluctuation trend across the period.

Table 10 Crude death rate per year and provinces of SA

Years	Mpumalanga	Northern Cape	North West	Western Cape	Eastern Cape	Free State	Gauteng	Kwazulu Natal	Limpopo
2004	1314.8	1138.3	1287.6	842.8	1179.9	1552.5	917.3	1362.2	446.7
2005	1422.8	1102.6	1288.9	910.9	1255.8	1637.0	909.1	1434.7	407.8
2006	1482.4	1055.7	1189.7	959.6	1217.7	1663.5	905.4	1411.5	398.1
2007	1320.9	1100.2	1155.4	890.2	1119.5	1561.5	871.6	1319.3	437.0
2008	1209.7	1024.6	1022.1	766.2	1048.3	1426.0	797.9	1178.2	449.0

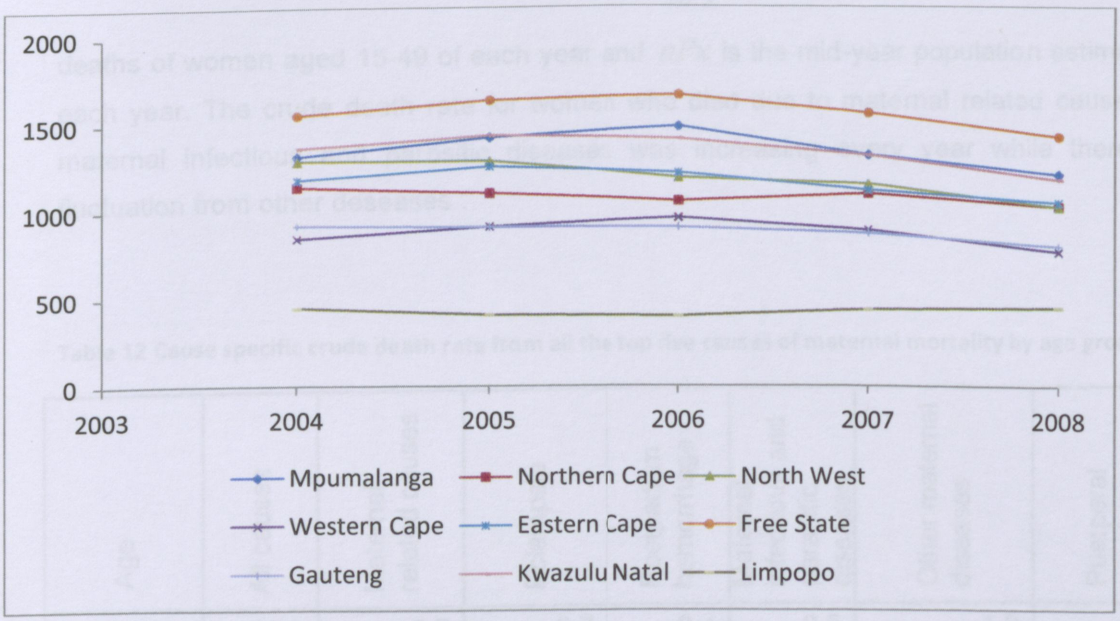

Figure 5 Crude death rate of women 15 – 49 years by provinces of SA

Table 10 and figure 7 show the crude death rate of women per province as a result of maternal related causes. The results show the increasing number of crude death rate in Mpumalanga, Northern Cape, North West and Western Cape, fluctuating death rates have been noted in Eastern Cape, Free State, Gauteng, Kwazulu Natal and Limpopo from 2003 to 2008. There is a general downward trend in the crude death rate over the period as shown in figure 5. Limpopo has consistently the highest crude death rates of women aged 15 to 49 over the period, with Mpumalanga having the lowest rates. The relative order of the provinces has remained unchanged over the six year period.

Year	All deaths	Maternal related causes	Eclampsia	Postpartum hemorrhage (O85)	Maternal infectious and parasitic diseases	Other maternal diseases	Puerperal sepsis (O72)
2003	959.8	7.8	0.7	0.7	0.5	1.6	0.9
2004	1090.3	9.5	0.8	0.8	1.1	3.6	1.0
2005	1122.6	10.4	0.7	0.9	1.3	3.8	1.1
2006	1110.7	11.4	0.8	0.9	1.6	4.2	1.3
2007	1053.5	15.0	0.6	0.8	2.5	6.3	1.2
2008	958.9	15.3	0.7	0.9	3.1	5.9	0.8

Table 11 Crude deaths rate per 100 000

The crude death rate is calculated as CDR = $\frac{nDx}{nPx} \times 100\ 000$, where nDx is the number deaths of women aged 15-49 of each year and nPx is the mid-year population estimates of each year. The crude death rate for women who died due to maternal related causes and maternal infectious and parasitic diseases was increasing every year while there is a fluctuation from other deseases .

Table 12 Cause specific crude death rate from all the top five causes of maternal mortality by age group

Age	All causes	Maternal related causes	Eclampsia	Postpartum hemorrhage	Maternal infectious and parasitic diseases	Other maternal diseases	Puerperal sepsis
15-19	174.9	5.7	0.7	0.4	0.5	1.9	0.3
20-24	607.8	13.3	1	1.2	2	4.7	0.6
25-29	1200.9	18.1	0.8	1.4	3.1	6.8	0.7
30-34	1546.3	18.8	1	1.2	3	6.8	1
35-39	1598.8	13.8	0.7	1	1.7	5.1	1
40-44	1544.7	5.6	0.3	0.3	0.5	2.1	0.6
45-49	1415.4	1.4	0	0.1	0.2	0.5	0.1

Table 12 shows increasing and decreasing rates in all the top five causes of maternal death, all causes and maternal related causes in SA from 2003 to 2008.

Table 13 Maternal mortality ratios per year

Year	Number of deaths	Deaths due to Maternal related causes	Number of Live births	MMR/100000
2003	127215	1032	904560	114
2004	138023	1206	991695	122
2005	140814	1308	1035656	126
2006	140859	1451	1060078	137
2007	134793	1930	1040947	185
2008	129109	2059	1055053	195

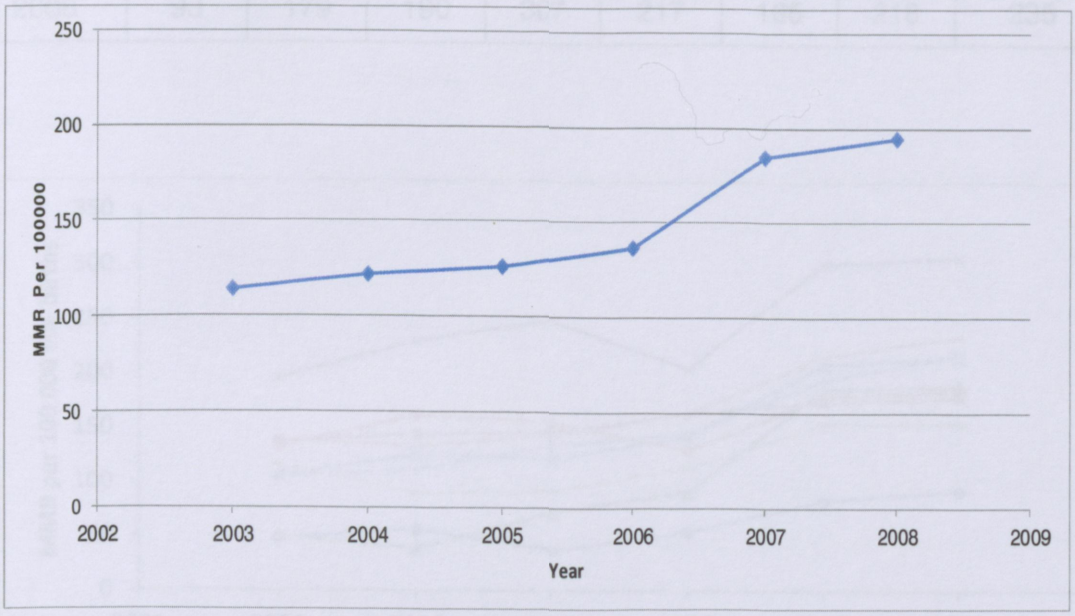

Figure 6 Overall maternal mortality ratios by year

Table 13 presents the maternal mortality ratios across the six year period within South Africa. Maternal mortality ratio is calculated as

$$MMR = \frac{\text{Number of maternal deaths}}{\text{Number of live births}} x100\ 000$$

And the results are shown graphically in figure 8. An inspection of the graph shows that maternal mortality ratio for South Africa increases steadily from 114 per 100000 live births in 2003 to 195 deaths per 100 000 live births in 2008. The number of deaths are increasing from 2003 to 2006 and start to declinein 2007 and 2008.

Table 14 Maternal mortality ratios by province

Year	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo
2003	48	137	51	195	106	132	105	138	116
2004	57	144	39	229	125	161	112	133	89
2005	38	146	73	249	122	156	134	143	93
2006	55	164	92	205	143	130	146	164	114
2007	84	175	186	302	209	180	195	217	155
2008	93	179	190	307	217	185	218	235	155

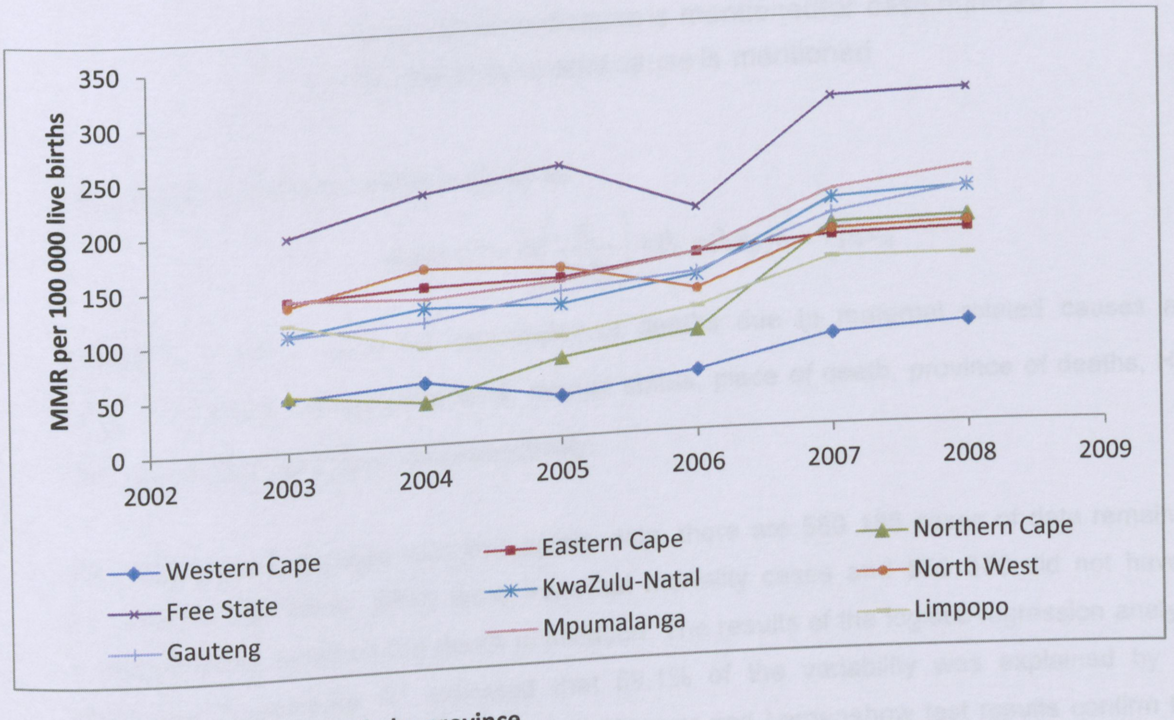

Figure 7 Maternal mortality ratio by province

Table 14 and figure 9 presents the maternal mortality ratios (MMR) per province in South Africa over the period 2003 to 2008. Overally, Western Cape consistently had the lowest maternal mortality rates though the national MMR has a steady increase from 48 per 100 000 live births in 2003 to 93 per 100000 live births in 2008. Free State province had the highest MMR each year, ranging from 195 in 2003 to 307 per 100 000 live births in 2008. The MMR in the Free State is four times the average of MMR of the Western Cape. MMR for Northern Cape province started out at almost the same level with Western Cape province in

Cape had increased to 190 deaths per 100 000 live births, almost double the MMR of Western Cape in 2008.

4.3 Logistic regression analysis

For the logistic regression analysis, the response variable, maternal, is defined as a death for which any of the maternal causes (O00 to O99 in the ICD-10 coding) is mentioned on the death notification either as an immediate or contributory cause of death. This dependent variable is modeled against the predictor variables which were mentioned in chapter 3. In this model all the predictor variables were entered. Since the most of the variable contained several missing values (coded as unknown or unspecified), the number of cases available for use is reduced significantly.

Thus, the dependent variable is

$$Y_i = \begin{cases} 1, & \text{Maternal related cause is mentioned for case number } i \\ 0, & \text{No maternal related cause is mentioned} \end{cases}$$

The logistic regression model is given by

$$\text{logit}(\pi_i) = \ell n\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + \beta_1 x_{1i} + \ldots + \beta_9 x_{9i}$$

Where $\pi_i = P(Y_i = 1))$ is the probability of deaths due to maternal related causes and $X_1,\ldots,X_9$ is age, educational level, marital status, place of death, province of deaths, HIV, TB, pneumonia, and diarrhea respectively.

After elimination of cases with incomplete data, there are 580 188 cases of data remaining for analysis. Of these, 6818 were maternal mortality cases and 573 370 did not have a maternal cause listed on the death notification. The results of the logistic regression analysis show that Nagelkerke R^2 indicated that 59.1% of the variability was explained by the independent variables in the model while Hosmer and Lemenshow test results confirm that the model estimates fit the data at an acceptable level since the *p*-value is greater than 0.05 (*p-value* = 0.111). Therefore we conclude that there is no significant difference between observed and predicted values and that the model adequately fits the data.

Table 15 Classification table

		Predicted: Maternal death is a contributing cause		% Correct
		No	Yes	
Maternal death is a contributing cause	No	466723	106647	81.4
	Yes	709	6109	89.6
Overall Percentage				81.5

Table 15, indicates that after including all the explanatory variables in the model, the model correctly classifies 81.5% as all cases.

Table 16 Parameter estimates for the model

	B	*se*(B)	Wald	df	*P*-values	e^B	95% C.I.for e^B	
							Lower	Upper
HIV	0.42	0.158	7.00	1	0.008	1.52	1.11	2.07
TB	5.66	0.359	248.08	1	0.000	287.21	142.00	580.88
Pneumonia	4.57	0.240	363.16	1	0.000	96.09	60.08	153.67
Diarrhea	4.03	0.330	148.59	1	0.000	56.06	29.34	107.10
Marital Status			47.28	3	0.000			
Age	-0.10	0.005	444.23	1	0.000	0.91	0.89	0.91
Death province			22.87	8	0.004			
Death place			478.50	4	0.000			
Educational Level			1.62	2	0.445			
Constant	-11.80	0.74	254.61	1	0.00	0.00		

Table 16 shows the results from the logistic regression model for the nine predictors of maternal death. The results show that only educational level out of nine independent variables was not significant in predicting maternal deaths. The most significant factors associated with maternal deaths are tb, pneumonia and diarrhea. The odds of tb being a contributory cause of death in addition to a maternal cause is estimated to be 287 times the odds for those who did not die from a maternal cause. (B = 5.660; odds ratio =287.207, p-value = 0.000). For pneumonia and diarrhea, the odds increase by factors of 96 and 56 respectively. Age is another factor associated with deaths from maternal causes. For every increase in age by 1 year, the odds of dying from a maternal cause goes down by approximately 10%, indicating that younger women are more likely to die from a maternal cause than older women. The other predictor variables that are significantly associated with maternal mortality are categorical, with more than two categories. These are province of death, educational level, marital status and place of death.

Table 17 The estimated results of the provinces of South Africa

	B	*se*(B)	Wald	df	*P*-values	e^B	95% C.I.for e^B	
							Lower	Upper
Limpopo	Reference							
Eastern Cape	0.400	0.214	3.500	1	0.061	1.491	0.981	2.266
Northern cape	-0.090	0.281	0.103	1	0.749	0.914	0.527	1.585
Free State	0.577	0.219	6.913	1	0.009	1.781	1.158	2.738
Kwazulu Natal	0.315	0.208	2.294	1	0.130	1.370	0.912	2.058
North west	0.378	0.232	2.645	1	0.104	1.459	0.925	2.299
Gauteng	0.344	0.220	2.447	1	0.118	1.410	0.917	2.168
Mpumalanga	0.626	0.218	8.247	1	0.004	1.870	1.220	2.868
Western Cape	0.509	0.223	5.205	1	0.023	1.663	1.074	2.575

Table 17 above shows the estimated results of all the provinces of South Africa. Limpopo province is considered as the reference province. The results show that women from Northern Cape province are estimated to be 10% less likely to die due to maternal related to pregnancy ($B=-0.090$, odds ratio $=0.914$, p-value $=0.749$) compared with Limpopo. Comparing Limpopo with the remaining provinces we observed that Mpumalanga ($B=0.626$, odds ratio $=1.870$, p-value $=0.004$) and Western Cape ($B=0.509$, odds ratio $=1.663$, p-value $=0.023$) had significantly higher risk of dying due to maternal related causes than Limpopo.

Table 18 The estimated results of the places of death

	B	se(B)	Wald	df	P-values	e^B	95% C.I.for e^B	
							Lower	Upper
Hospital	Reference							
Emergency	-0.297	0.225	1.73	1	0.188	0.743	0.478	1.156
Dead arrival	-0.714	0.190	14.07	1	0.000	0.490	0.337	0.711
Nursing home	-2.040	0.355	32.99	1	0.000	0.130	0.065	0.261
Home	-1.521	0.071	457.82	1	0.000	0.219	0.190	0.251

From table 18, we can easily observe the estimated results of the places where women died due to maternal related causes taking the reference as a hospital. The results showed that women who died at the emergency room (B=–0.297, odds ratio =0.743, p-value =0.188), dead at arrival (B=–0.714, odds ratio =0.490, p-value =0.000), nursing home (B=–2.040, odds ratio =0.130, p-value =0.000) and at home (B=–1.521, odds ratio =0.219, p-value =0.000) were less likely to die of maternal causes compared to those who died at the hospital.

Table 19 The estimated results of the marital status

	B	se	Wald	df	P- values	e^B	95% C.I.for e^B	
							Lower	Upper
Single	Reference							
Married	0.901	0.383	5.520	1	0.019	2.462	1.161	5.220
Widowed	1.368	0.385	12.605	1	0.000	3.928	1.846	8.360
Divorced	0.464	0.451	1.059	1	0.303	1.591	0.657	3.854

Table 19 summarizes the association of marital status with maternal deaths, According to the model widowed women had an estimate of four times more likely to die of maternal causes than those who were single(B=1.368, odds ratio =3.928, p-value =0.000). Married women were 2.5 times more likely to die of maternal factors than those who were single women (B=0.901,odds ratio = 2.462, p-value = 0.019) and there is no significant difference between divorced women and single women (B= 0.464,odds ratio = 1.591, p-value = 0.303).

4.4 Log linear analysis

From the logistic regression, there exist significant associations between maternal deaths and other causes of death, namely HIV, TB, pneumonia (PN) and diarrhea (DR). Log linear models are used to explore the associations. A backwards elimination stepwise procedure is adopted in the search for the most parsimonious model.

When only four causes are listed, we can investigate the inter-relationships among four of the five variables (MT, TB, HIV, PN and DR) at a time. MT must always be in the model since the primary focus is on maternal deaths, hence the following models were considered in the case where for four causes are listed:

- MT, HIV, TB, and PN
- MT, HIV, TB, and DR
- MT, PN, DR, and TB
- MT, HIV, PN and DR

When three causes are listed, then only three of the variables of interest can be investigated at a time. Keeping MT in all models, the following sets of variables can be considered:

MT, HIV and TB

- MT, HIV and PN
- MT, HIV and DR
- MT, TB, and PN
- MT, TB, and DR
- MT, PN and DR

The main results are discussed in this section, with the details of the selection provided in Appendix.

4.4.1 Log-Linear analysis for models when four causes are listed

(a) MT, HIV, TB and PN

All four variables were entered and the backwards elimination procedure of stepwise regression analysis used to find the most parsimonious model that fits the data. The best model found is the hierarchical model generated by the interaction terms MT*TB*PN, HIV*TB and HIV*TB. This model has a chi-square value of 2.491 with 6 degrees of freedom and a p-value of 0.870. This model implies a three-way interaction among the variables MT, TB and PN, and a two-way interaction between HIV and PN. Thus, maternal deaths are not related directly to HIV deaths. Any associations will be indirectly, through the association of HIV with TB.

(b) MT, HIV, TB, DR

PN is removed from the list of variables and DR substituted. Backward stepwise procedure was again applied to determine the most parsimonious model. In this case, the most parsimonious model is generated by the following interactions: HIV*TB*DR, MT*TB and MT*DR. The model has a chi-square value of 2.156 with 5 degrees of freedom and a p-value of 0.827. The result again shows no direct association between maternal deaths and deaths due to HIV. An indirect association may exist through the association of HIV with TB and DR, both of which are directly associated with maternal deaths.

(c) MT, TB, PN, DR

When TB, PN and DR are combined with MT, the most parsimonious model is generated by MT*TB*PN, TB*PN*DR and MT*DR. The model so generated has a chi-square value of 1.856 with 3 degrees of freedom and a p-value of 0.603. The results indicate an association between MT and DR, separately from a three-way association among MT, PN and TB.

(d) MT, HIV, PN, DR

The last model considered for the case of four causes is based on the variables MT, HIV, PN, and DR. The best model is generated by HIV*PN*DR, MT*PN, MT*DR. The model has a chi-square value of 5.594 with the 5 degrees of freedom and a p-value is 0.348. This model shows again that there is no direct link between maternal deaths and HIV deaths. The direct links are with deaths due to pneumonia and diarrhoea.

The analysis of the cases with four variables has demonstrated that there is not a direct link between HIV deaths and maternal deaths (as listed on the death notifications).

4.4.2 Log-linear analysis cases with three causes of death

Associations between maternal deaths MT and HIV, TB, PN and DR are investigated two at a time for cases where three causes of death are listed on the death notification forms.

Table 20 Generating classes for cases with three causes listed

Variables	Generating Class	Likelihood Ratio Chi-square	df	p-value
MT, HIV, TB	MT*HIV, MT*TB, HIV*TB	1.956	1	0.162
MT, HIV, PN	MT*HIV, MT*PN, HIV*PN	0.183	1	0.669
MT, HIV, DR	MT*HIV, MT*DR, HIV*DR	0.798	1	0.372
MT, PN, DR	MT*DR, MT*PN, PN*DR	0.196	1	0.658
MT, TB, PN	Saturated			
MT, TB, DR	Saturated			

A summary of the generating classes and appropriate statistics is presented in Table 4.27 above.

In four of the possible combinations of variables, no significant three-way interactions were found. The generating classes each consisted of all two-way interactions. This implies that, for these cases, direct associations exist between MT and each of HIV, TB, PN and DR. For the remaining two combinations the best fitting model is saturated. Thus, there is a significant three-way interaction among MT, TB and PN and among MT, TB and DR.

When only two causes of death listed, the model explored can only be MT with one other variable. In all cases, the best fitting two-variable model was saturated. This implies that maternal mortality was significantly associated with each of HIV, TB, PN and DR when only two causes of death are listed on the notification form.

Chapter 5: Discussion, conclusion and recommendations

5.1 Data considerations:

The data set used for this study was obtained from Statistics South Africa. It consisted of individual records captured from death notification forms for deaths in South Africa between 2003 and 2008.

A major drawback concerning the data is the high level of missing values for the demographic variables. Several cases have missing demographic variables and hence modelling of causes of death against demographic variables resulted in loss of a large proportion of the data since logistic regression modelling requires complete data. Further, there is no indication that the causes of death were ascertained by autopsies. The general impression is that the vast majority of the deaths were not autopsied and hence the assignment of causes of death is imprecise. In fact, the information accompanying the data stated that verbal autopsies were used to identify the causes of deaths. Thus, for example, a large proportion of deaths attributed to maternal causes were coded (using ICD-10) as

O98: maternal infections and parasitic diseases classified elsewhere but complicating pregnancy, childbirth and the peurperium and

O99: other maternal diseases classified elsewhere but complicating pregnancy, child birth and the peurperium

These definitions for these codes suggest that the classification of the causes of death was not precise. Other problems with the data involve data capture errors that were not corrected. An example is where the immediate cause of death for persons over 15 years of age was captured as "Stillbirth". One can only imagine what other hidden errors are present in the data.

Immediate causes of death were recorded for each case. In addition, up to five other causes leading to death were also recorded. From the information, an underlying cause of death was imputed.

5.2 Leading Causes

The results show that the top five immediate causes of maternal mortality in South Africa from 2003 to 2008 were

- Eclampsia,
- Post-partum hemorrhage,
- Puerperal sepsis,
- Maternal infections and parasitic diseases classified elsewhere but complicating pregnancy, childbirth and the peurperium
- Other maternal diseases classified elsewhere but complicating pregnancy, child birth and the peurperium.

The 2005–2007 Saving Mothers Report showed that the five major causes of maternal death in South Africa remained the same during 2005–2007 and 2002–2004 and were: non pregnancy-related infections mainly AIDS (43,7%), complications of hypertension (15,7%), obstetric hemorrhage (12,4%), pregnancy-related sepsis (9,0%), and pre-existing maternal disease (6,0%)(Saving Mothers 2005–2007). The result from the analysis of the STATSSA is totally different from the Saving Mothers Report. They did not use the STATSSA data and hence obtained different results.

5.3 Trends in mortality

The analysis indicates that there is an increasing trend in the maternal mortality ratio from 114 per 100 000 live births in 2003 to 195 per 100000 live births in 2008, which is in line with the results found by Moodle J and Pattinson RC (2003). Additionally, Finance Minister Pravin Gordhan in Parliament stated that South Africa's maternal mortality rate increased from 369 deaths per 100 000 births in 2001, to 625 in 2007 (South African news, internet). These ratios stated by the minister are also much higher than the rates compute with the STATSSA causes of death data. The analysis by province shows that the Free State consistently has the highest overall maternal mortality rate every year from 2003 to 2008. The province with the lowest maternal mortality rate is the Western Cape. In 2003 and 2004, Western Cape and Northern Cape provinces had the lowest maternal mortality ratios of about 50 per 100 000 live births. From 2005 to 2008, the mortality ratios for Northern Cape province began an upward climb while Western Cape remained at almost the same level with a slight increase in 2007/2008. By 2008, the maternal mortality ratio for Northern Cape had reached 195 per 100 000 live births. In line with the overall maternal mortality rates, there is an increasing trend the cause specific crude death rates.

According to Dorrington (2012), the indications are that by 2009, South Africa had not yet managed to reverse the upward trend in MMR. The author claims that the increase is largely a result of an increase in the number of maternal deaths from indirect causes, as might be expected in the context of the HIV pandemic.

5.4 Statistical Modelling

A logistic regression model was fitted to investigate any relationships that might exist between maternal mortality one hand and a set of demographic and clinical variables on the other hand. Logistic regression modeling requires complete data and hence cases with missing values on the variables used for the logistic regression were omitted. This resulted in a reduction of the number of observations available for the regression analysis. The results show that the most important demographic variables associated with maternal deaths are marital status, age, provinces and place of deaths while education was not significant. Other causes of death that are associated with maternal mortality are TB, HIV, pneumonia and diarrhea. Comparing other provinces against Limpopo province, Mpumalanga and Western Cape women were more likely to die due to maternal related causes while in Northern Cape they were less likely to die of maternal causes. Marital status is also statistically associated with maternal mortality. It is worth noting that married and widowed women were more likely to die from maternal causes, compared to single and divorced women. The model performed reasonably well in predicting maternal deaths, with an overall accuracy of 81.5% correct classifications. The model predicts non-maternal deaths with 81.4% accuracy and maternal deaths with 89.4% accuracy. However, the R^2 value of 59.1% indicates that about 39% of variability in the data was unexplained. This is probably due to the large amount of data that was dropped because of missing values and the fact that there could be variables such as poverty and lifestyle variables that were not included in the data.

Log linear models were used to assess the relationship between maternal related causes and clinical factors such as TB, HIV, DR and PN. The results show a significant association of maternal deaths with HIV, TB, pneumonia and diarrhea. The association may be direct or indirect, depending on the number of causes of death listed for each observation. When four or more causes of death are listed, there is no direct association between maternal deaths and HIV. Rather, a direct relation exists between maternal deaths and the so-called opportunistic infections associated with HIV. It would appear that instead of listing HIV as contributing factor to maternal death, the opportunistic infections are mentioned instead. When two or three causes of death are listed, then we observe direct associations of maternal deaths with HIV.

5.5 Concluding remarks and recommendations

It is very important that STATSSA pay attention to its data capture routines. Some of the problems encountered in this project would not have been there if the data capture system was able to detect glaring errors such as attributing to the cause of death of a person above the age of 15 years as "Stillbirth". It will also be more useful if causes of death are verified by autopsies. The health related issues of the nation cannot be addressed if the causes of death, for instance, are ascertained non-scientifically. Every effort needs to be made to complete the death notification forms as completely as possible, instead of using short-cut phrases such as "unknown" or "unspecified".

Based on the findings we recommend the following action plans to reduce the trend of maternal deaths among women of reproductive age in South Africa. Investment should be put on safe motherhood. This would enhance a process whereby all pregnant women have access to a skilled attendant at the time of delivery and to the necessary care for obstetric complications when they arise. It would also enhance antenatal care to potential complications that may arise.

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Appendices

Appendix 1 Mid year estimates per year and province (2003-2008)

	2004	2005	2006	2007	2008	Total
Mpumalanga	869545	852600	862500	941000	981900	4507545
Northern cape	236226	228000	228100	276500	296400	1265226
North west	999725	978800	986000	856100	924600	4745225
Western cape	1292977	1283100	1309100	1327400	1508400	6720977
Eastern cape	1834921	1793900	1798300	1769400	1737200	8933721
Free state	820357	802000	803000	802100	813200	4040657
Gaunteng	2565335	2538600	2567000	2697800	2958200	13326935
Kwazulu Natal	2628664	2581600	2609300	2683100	2841000	13343664
Limpopo	1397011	1479600	1503100	1429900	1403900	7213511
Total	12644761	12538200	12666400	12783300	13464800	64097461

Appendix 2 Mid year estimates per year and age group

Age group	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**
15-19years	2668543	2448341	2447200	2461100	2479300	2556200	15060684
20-24years	2235677	2320855	2286600	2321000	2329700	2414400	13908232
25-29years	2121326	2111636	2062800	2104200	2131500	2245400	12776862
30-34years	1788812	1843665	1873800	1909000	1906400	2020200	11341877
35-39years	1724332	1449763	1416300	1448600	1510800	1689300	9239095
40-44years	1489092	1312067	1293800	1269900	1254800	1307600	7927259
45-49years	1219624	1157891	1157500	1162400	1171400	1231500	7100315
Total	13247406	12644218	12538000	12676200	12783900	13464600	77354324

Appendix 3 Number of live births per age group and year (2003-2008)

Age group	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**
15-19	7346	7793	8196	8259	8323	8585	48502
20-24	14592	16002	16680	16829	16283	16682	97068
25-29	12512	13380	14008	13989	14502	14986	83377
30-34	9324	9888	10113	10094	9951	10046	59416
35-39	5020	5394	5624	5535	5708	5563	32844
40-44	1738	1654	1753	1639	1649	1624	10057
45-49	182	125	175	133	132	114	861
Total	50714	54236	56549	56478	56548	57600	332125

Appendix 4 Categorical Variables Codings

Categorical Variables Codings										
		Frequency	Parameter coding							
			1	2	3	4	5	6	7	8
Province of death	Limpopo	452	1	0	0	0	0	0	0	0
	Eastern Cape	1967	0	1	0	0	0	0	0	0
	Northern Cape	237	0	0	1	0	0	0	0	0
	Free State	1285	0	0	0	1	0	0	0	0
	KwaZulu-Natal	3535	0	0	0	0	1	0	0	0
	North West	1038	0	0	0	0	0	1	0	0
	Gauteng	2111	0	0	0	0	0	0	1	0
	Mpumalanga	1415	0	0	0	0	0	0	0	1
	Western Cape	1231	0	0	0	0	0	0	0	0
EduLevel	None	569	1	0	0	0	0			
	Primary	2266	0	1	0	0	0			
	Secondary	4518	0	0	1	0	0			
	Tertiary	271	0	0	0	1	0			
	unknown	31	0	0	0	0	1			
	Unspecified	5616	0	0	0	0	0			
Year of death	2003	1767	1	0	0	0	0			
	2004	2056	0	1	0	0	0			
	2005	2134	0	0	1	0	0			
	2006	2261	0	0	0	1	0			
	2007	2539	0	0	0	0	1			
	2008	2514	0	0	0	0	0			
Place of death	Hospital (in-patient)	9060	1	0	0	0				
	Emergency room/out-patient	272	0	1	0	0				
	Dead on arrival	318	0	0	1	0				
	Nursing home	131	0	0	0	1				
	Home	3490	0	0	0	0				
MARITAL STATUS	Single	10098	1	0	0					
	Married	2872	0	1	0					
	Widowed	206	0	0	1					
	Divorced	95	0	0	0					
TB	No	11697	1							
	Yes	1574	0							
DIARRHEOA	No	12665	1							
	Yes	606	0							
PNEUMONIA	No	11921	1							
	Yes	1350	0							
HIV	No	12715	1							
	Yes	556	0							

Appendix 5 Step summary for MT, HIV, TB, and PN

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*HIV*TB*PN	0.000	0		
	Deleted Effect	1	MT*HIV*TB*PN	.000	1	1.000	2
1	Generating Class[b]		MT*HIV*TB, MT*HIV*PN, MT*TB*PN, HIV*TB*PN	.000	1	1.000	
	Deleted Effect	1	MT*HIV*TB	.327	1	.568	2
		2	MT*HIV*PN	.967	1	.325	2
		3	MT*TB*PN	4.474	1	.034	2
		4	HIV*TB*PN	.218	1	.641	3
2	Generating Class[b]		MT*HIV*TB, MT*HIV*PN, MT*TB*PN	.218	2	.897	
	Deleted Effect	1	MT*HIV*TB	.322	1	.571	3
		2	MT*HIV*PN	.946	1	.331	2
		3	MT*TB*PN	4.496	1	.034	3
3	Generating Class[b]		MT*HIV*PN, MT*TB*PN, HIV*TB	.539	3	.910	
	Deleted Effect	1	MT*HIV*PN	1.241	1	.265	2
		2	MT*TB*PN	4.801	1	.028	3
		3	HIV*TB	67.041	1	.000	2
4	Generating Class[b]		MT*TB*PN, HIV*TB, MT*HIV, HIV*PN	1.780	4	.776	
	Deleted Effect	1	MT*TB*PN	4.675	1	.031	3
		2	HIV*TB	66.851	1	.000	2
		3	MT*HIV	.661	1	.416	2
		4	HIV*PN	.029	1	.864	2
5	Generating Class[b]		MT*TB*PN, HIV*TB, MT*HIV	1.809	5	.875	
	Deleted Effect	1	MT*TB*PN	4.676	1	.031	2
		2	HIV*TB	67.403	1	.000	2
		3	MT*HIV	.681	1	.409	2
6	Generating Class[b]		MT*TB*PN, HIV*TB	2.491	6	.870	
	Deleted Effect	1	MT*TB*PN	4.675	1	.031	3
		2	HIV*TB	68.83	1	.000	2
7	Generating Class[b]		MT*TB*PN, HIV*TB	2.491	6	0.870	

Appendix 6 Parameter Estimates MT, HIV, TB, and PN

Parameter EstimatesMT, HIV, TB, and PN

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-.693	1.414	-.490	.624	-3.464	2.078
[MT = 0]	5.130	1.418	3.617	.000	2.351	7.909
[MT = 1]	0^a	.	.	.	.	.
[HIV = 0]	1.099	1.633	.673	.501	-2.101	4.299
[HIV = 1]	0^a	.	.	.	.	.
[TB = 0]	-1.004E-013	2.000	.000	1.000	-3.919	3.919
[TB = 1]	0^a	.	.	.	.	.
[PN = 0]	-1.004E-013	2.000	.000	1.000	-3.919	3.919
[PN = 1]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 0]	.484	1.637	.296	.767	-2.724	3.693
[MT = 0] * [HIV = 1]	0^a	.	.	.	.	.
[MT = 1] * [HIV = 0]	0^a	.	.	.	.	.
[MT = 1] * [HIV = 1]	0^a	.	.	.	.	.
[MT = 0] * [TB = 0]	.864	2.004	.431	.666	-3.063	4.791
[MT = 0] * [TB = 1]	0^a	.	.	.	.	.
[MT = 1] * [TB = 0]	0^a	.	.	.	.	.
[MT = 1] * [TB = 1]	0^a	.	.	.	.	.
[MT = 0] * [PN = 0]	1.428	2.003	.713	.476	-2.498	5.355
[MT = 0] * [PN = 1]	0^a	.	.	.	.	.
[MT = 1] * [PN = 0]	0^a	.	.	.	.	.
[MT = 1] * [PN = 1]	0^a	.	.	.	.	.
[HIV = 0] * [TB = 0]	1.299	2.202	.590	.555	-3.016	5.614
[HIV = 0] * [TB = 1]	0^a	.	.	.	.	.
[HIV = 1] * [TB = 0]	0^a	.	.	.	.	.
[HIV = 1] * [TB = 1]	0^a	.	.	.	.	.
[HIV = 0] * [PN = 0]	1.002E-013	2.309	.000	1.000	-4.526	4.526
[HIV = 0] * [PN = 1]	0^a	.	.	.	.	.
[HIV = 1] * [PN = 0]	0^a	.	.	.	.	.
[HIV = 1] * [PN = 1]	0^a	.	.	.	.	.
[TB = 0] * [PN = 0]	3.135	2.467	1.271	.204	-1.699	7.970
[TB = 0] * [PN = 1]	0^a	.	.	.	.	.
[TB = 1] * [PN = 0]	0^a	.	.	.	.	.
[TB = 1] * [PN = 1]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 0] * [TB = 0]	-.790	2.206	-.358	.720	-5.114	3.534
[MT = 0] * [HIV = 0] * [TB = 1]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 1] * [TB = 0]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 1] * [TB = 1]	0^a	.	.	.	.	.
[MT = 1] * [HIV = 0] * [TB = 0]	0^a	.	.	.	.	.
[MT = 1] * [HIV = 0] * [TB = 1]	0^a	.	.	.	.	.
[MT = 1] * [HIV = 1] * [TB = 0]	0^a	.	.	.	.	.
[MT = 1] * [HIV = 1] * [TB = 1]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 0] * [PN = 0]	-.031	2.313	-.014	.989	-4.565	4.502
[MT = 0] * [HIV = 0] * [PN = 1]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 1] * [PN = 0]	0^a	.	.	.	.	.
[MT = 0] * [HIV = 1] * [PN = 1]	0^a	.	.	.	.	.

[MT = 1] * [HIV = 0] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 0] * [PN = 0]	-3.779	2.471	-1.529	.126	-8.622	1.064
[MT = 0] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[HIV = 0] * [TB = 0] * [PN = 0]	-.135	2.758	-.049	.961	-5.542	5.271
[HIV = 0] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[HIV = 0] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[HIV = 0] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[HIV = 1] * [TB = 0] * [PN = 0]	0[a]	.	.	.	.	.
[HIV = 1] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[HIV = 1] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[HIV = 1] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 0] * [TB = 0] * [PN = 0]	.208	2.763	.075	.940	-5.208	5.623
[MT = 0] * [HIV = 0] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 0] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 0] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 1] * [TB = 0] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 1] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 1] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 1] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0] * [TB = 0] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1] * [TB = 0] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

b. Model: Poisson

c. Design: Constant + MT + HIV + TB + PN + MT * HIV + MT * TB + MT * PN + HIV * TB + HIV * PN + TB * PN + MT * HIV * TB + MT * HIV * PN + MT * TB * PN + HIV * TB * PN + MT * HIV * TB * PN

Appendix 7 Step Summary for MT, HIV, TB and DR

Step Summary for MT, HIV, TB and DR

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*HIV*TB*DR	.000	0	.	
	Deleted Effect	1	MT*HIV*TB*DR	.000	1	1.000	2
1	Generating Class[b]		MT*HIV*TB, MT*HIV*DR, MT*TB*DR, HIV*TB*DR	.000	1	1.000	
	Deleted Effect	1	MT*HIV*TB	.670	1	.413	2
		2	MT*HIV*DR	.753	1	.386	2
		3	MT*TB*DR	.095	1	.758	2
		4	HIV*TB*DR	6.000	1	.014	3
2	Generating Class[b]		MT*HIV*TB, MT*HIV*DR, HIV*TB*DR	.095	2	.954	
	Deleted Effect	1	MT*HIV*TB	.656	1	.418	3
		2	MT*HIV*DR	.744	1	.388	3
		3	HIV*TB*DR	5.994	1	.014	3
3	Generating Class[b]		MT*HIV*DR, HIV*TB*DR, MT*TB	.750	3	.861	
	Deleted Effect	1	MT*HIV*DR	.732	1	.392	3
		2	HIV*TB*DR	5.953	1	.015	3
		3	MT*TB	75.698	1	.000	2
4	Generating Class[b]		HIV*TB*DR, MT*TB, MT*HIV, MT*DR	1.483	4	.830	
	Deleted Effect	1	HIV*TB*DR	5.870	1	.015	3
		2	MT*TB	75.584	1	.000	2
		3	MT*HIV	.674	1	.412	3
		4	MT*DR	38.537	1	.000	2
5	Generating Class[b]		HIV*TB*DR, MT*TB, MT*DR	2.156	5	.827	
	Deleted Effect	1	HIV*TB*DR	6.008	1	.014	3
		2	MT*TB	77.323	1	.000	2
		3	MT*DR	38.544	1	.000	2
6	Generating Class[b]		HIV*TB*DR, MT*TB, MT*DR	2.156	5	.827	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.

b. Statistics are displayed for the best model at each step after step 0.

c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 8 Parameter Estimates MT, HIV, TB, and PN

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-14.470	298.852	-.048	.961	-600.209	571.268
[MT = 0]	18.351	298.852	.061	.951	-567.388	604.089
[MT = 1]	0[a]	.	.	.	.	.
[HIV = 0]	1.936	.032	59.633	.000	1.872	1.999
[HIV = 1]	0[a]	.	.	.	.	.
[TB = 0]	13.786	298.852	.046	.963	-571.953	599.526
[TB = 1]	0[a]	.	.	.	.	.
[DR = 0]	13.093	298.853	.044	.965	-572.647	598.833
[DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 0] * [DR = 0]	-24.389	597.704	-.041	.967	-1195.868	1147.089
[MT = 0] * [TB = 0] * [DR = 1]	-12.536	298.852	-.042	.967	-598.275	573.204
[MT = 0] * [TB = 1] * [DR = 0]	-11.382	298.853	-.038	.970	-597.122	574.359
[MT = 0] * [TB = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0] * [DR = 0]	-9.675	298.853	-.032	.974	-595.416	576.066
[MT = 1] * [TB = 0] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 0] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + MT + HIV + TB + DR + MT * TB * DR + MT * DR

Appendix 9 Step Summary for MT, TB, PN and DR

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*TB*PN*DR	.000	0	.	
	Deleted Effect	1	MT*TB*PN*DR	.000	1	.986	2
1	Generating Class[b]		MT*TB*PN, MT*TB*DR, MT*PN*DR, TB*PN*DR	.000	1	.986	
	Deleted Effect	1	MT*TB*PN	4.657	1	.031	2
		2	MT*TB*DR	.152	1	.697	2
		3	MT*PN*DR	1.783	1	.182	2
		4	TB*PN*DR	49.540	1	.000	3
2	Generating Class[b]		MT*TB*PN, MT*PN*DR, TB*PN*DR	.152	2	.927	
	Deleted Effect	1	MT*TB*PN	4.588	1	.032	3
		2	MT*PN*DR	1.703	1	.192	3
		3	TB*PN*DR	49.694	1	.000	3
3	Generating Class[b]		MT*TB*PN, TB*PN*DR, MT*DR	1.856	3	.603	
	Deleted Effect	1	MT*TB*PN	4.374	1	.036	3
		2	TB*PN*DR	49.863	1	.000	3
		3	MT*DR	33.698	1	.000	2
4	Generating Class[b]		MT*TB*PN, TB*PN*DR, MT*DR	1.856	3	.603	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 10 Parameter Estimates MT, TB, PN and DR

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-4.530	1.132	-4.004	.000	-6.748	-2.313
[MT = 0]	8.219	1.121	7.334	.000	6.022	10.416
[MT = 1]	0[a]	.	.	.	.	.
[TB = 0]	3.008	1.109	2.713	.007	.835	5.181
[TB = 1]	0[a]	.	.	.	.	.
[PN = 0]	.837	1.425	.587	.557	-1.956	3.629
[PN = 1]	0[a]	.	.	.	.	.
[DR = 0]	4.520	.535	8.444	.000	3.470	5.569
[DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 0] * [PN = 0]	-.788	2.289	-.344	.731	-5.274	3.699
[MT = 0] * [TB = 0] * [PN = 1]	-.501	1.097	-.456	.648	-2.650	1.649
[MT = 0] * [TB = 1] * [PN = 0]	1.315	1.415	.929	.353	-1.458	4.089
[MT = 0] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0] * [PN = 0]	2.006	1.497	1.340	.180	-.929	4.941
[MT = 1] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[TB = 0] * [PN = 0] * [DR = 0]	-1.076	.169	-6.354	.000	-1.408	-.744
[TB = 0] * [PN = 0] * [DR = 1]	0[a]	.	.	.	.	.
[TB = 0] * [PN = 1] * [DR = 0]	-1.432	.173	-8.272	.000	-1.772	-1.093
[TB = 0] * [PN = 1] * [DR = 1]	0[a]	.	.	.	.	.
[TB = 1] * [PN = 0] * [DR = 0]	-.851	.175	-4.857	.000	-1.195	-.508
[TB = 1] * [PN = 0] * [DR = 1]	0[a]	.	.	.	.	.
[TB = 1] * [PN = 1] * [DR = 0]	0[a]	.	.	.	.	.
[TB = 1] * [PN = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [DR = 0]	-2.088	.509	-4.099	.000	-3.086	-1.090
[MT = 0] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + MT + TB + PN + DR + MT * TB * PN + TB * PN * DR + MT * DR

Appendix 11 Step Summary MT, HIV, PN AND DR

Step Summary MT, HIV, PN AND DR							
Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*HIV*PN*DR	.000	0	.	
	Deleted Effect	1	MT*HIV*PN*DR	.000	1	.999	2
1	Generating Class[b]		MT*HIV*PN, MT*HIV*DR, MT*PN*DR, HIV*PN*DR	.000	1	.999	
	Deleted Effect	1	MT*HIV*PN	1.030	1	.310	2
		2	MT*HIV*DR	.587	1	.444	2
		3	MT*PN*DR	1.435	1	.231	2
		4	HIV*PN*DR	15.527	1	.000	2
2	Generating Class[b]		MT*HIV*PN, MT*PN*DR, HIV*PN*DR	.587	2	.746	
	Deleted Effect	1	MT*HIV*PN	1.097	1	.295	2
		2	MT*PN*DR	1.584	1	.208	3
		3	HIV*PN*DR	15.427	1	.000	2
3	Generating Class[b]		MT*PN*DR, HIV*PN*DR, MT*HIV	1.684	3	.640	
	Deleted Effect	1	MT*PN*DR	1.661	1	.197	3
		2	HIV*PN*DR	15.363	1	.000	2
		3	MT*HIV	2.208	1	.137	2
4	Generating Class[b]		HIV*PN*DR, MT*HIV, MT*PN, MT*DR	3.345	4	.502	
	Deleted Effect	1	HIV*PN*DR	15.404	1	.000	2
		2	MT*HIV	2.249	1	.134	3
		3	MT*PN	42.192	1	.000	2
		4	MT*DR	30.995	1	.000	2
5	Generating Class[b]		HIV*PN*DR, MT*PN, MT*DR	5.594	5	.348	
	Deleted Effect	1	HIV*PN*DR	15.682	1	.000	2
		2	MT*PN	42.356	1	.000	2
		3	MT*DR	30.978	1	.000	2
6	Generating Class[b]		HIV*PN*DR, MT*PN, MT*DR	5.594	5	.348	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 12 Parameter Estimates MT, HIV, PN AND DR

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-4.144	.658	-6.294	.000	-5.435	-2.854
[MT = 0]	7.755	.638	12.158	.000	6.505	9.005
[MT = 1]	0[a]	.	.	.	.	.
[PN = 0]	3.434	.457	7.514	.000	2.538	4.329
[PN = 1]	0[a]	.	.	.	.	.
[DR = 0]	3.915	.538	7.272	.000	2.860	4.970
[DR = 1]	0[a]	.	.	.	.	.
[HIV = 0]	2.592	.170	15.205	.000	2.258	2.926
[HIV = 1]	0[a]	.	.	.	.	.
[HIV = 0] * [PN = 0] * [DR = 0]	-1.159	.348	-3.333	.001	-1.840	-.477
[HIV = 0] * [PN = 0] * [DR = 1]	-.693	.191	-3.629	.000	-1.067	-.319
[HIV = 0] * [PN = 1] * [DR = 0]	-.757	.184	-4.120	.000	-1.117	-.397
[HIV = 0] * [PN = 1] * [DR = 1]	0[a]	.	.	.	.	.
[HIV = 1] * [PN = 0] * [DR = 0]	-.495	.198	-2.506	.012	-.882	-.108
[HIV = 1] * [PN = 0] * [DR = 1]	0[a]	.	.	.	.	.
[HIV = 1] * [PN = 1] * [DR = 0]	0[a]	.	.	.	.	.
[HIV = 1] * [PN = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [DR = 0]	-2.019	.509	-3.967	.000	-3.016	-1.022
[MT = 0] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [PN = 0]	-1.997	.419	-4.767	.000	-2.819	-1.176
[MT = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [PN = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + MT + PN + DR + HIV + HIV * PN * DR + MT * DR + MT * PN

Appendix 13 Step Summary of MT, HIV and TB

Step Summary of MT, HIV and TB

Step[a]			Effects	Ch-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*HIV*TB	.000	0	.	
	Deleted Effect	1	MT*HIV*TB	1.956	1	.162	2
1	Generating Class[b]		MT*HIV, MT*TB, HIV*TB	1.956	1	.162	
	Deleted Effect	1	MT*HIV	8.308	1	.004	2
		2	MT*TB	316.474	1	.000	2
		3	HIV*TB	218.652	1	.000	2
2	Generating Class[b]		MT*HIV, MT*TB, HIV*TB	1.956	1	.162	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.

c. For 'Deleted Effect', this is the change in the Chi-Square after the efect is deleted from the model.

Appendix 14 Parameter Estimates MT, HIV and PN

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-.088	.366	-.241	.810	-.806	.630
[MT = 0]	7.353	.366	20.117	.000	6.637	8.069
[MT = 1]	0[a]	.	.	.	.	.
[HIV = 0]	2.178	.169	12.880	.000	1.847	2.509
[HIV = 1]	0[a]	.	.	.	.	.
[TB = 0]	3.728	.337	11.053	.000	3.067	4.389
[TB = 1]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 0]	-.451	.167	-2.703	.007	-.778	-.124
[MT = 0] * [HIV = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1]	0[a]	.	.	.	.	.
[HIV = 0] * [TB = 0]	.543	.036	15.076	.000	.473	.614
[HIV = 0] * [TB = 1]	0[a]	.	.	.	.	.
[HIV = 1] * [TB = 0]	0[a]	.	.	.	.	.
[HIV = 1] * [TB = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 0]	-3.244	.336	-9.657	.000	-3.903	-2.586
[MT = 0] * [TB = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + MT + HIV + TB + MT * HIV + HIV * TB + MT * TB

Appendix 15 Step Summary MT, HIV and DR

Step Summary MT, HIV and DR

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*HIV*DR	.000	0	.	
	Deleted Effect	1	MT*HIV*DR	.798	1	.372	2
1	Generating Class[b]		MT*HIV, MT*DR, HIV*DR	.798	1	.372	
	Deleted Effect	1	MT*HIV	18.650	1	.000	2
		2	MT*DR	172.028	1	.000	2
		3	HIV*DR	31.100	1	.000	2
2	Generating Class[b]		MT*HIV, MT*DR, HIV*DR	.798	1	.372	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 16 Parameter Estimates MT, HIV and DR

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-.949	.390	-2.434	.015	-1.713	-.185
[HIV = 0] * [DR = 0]	7.311	.396	18.455	.000	6.534	8.087
[HIV = 0] * [DR = 1]	2.979	.173	17.263	.000	2.641	3.317
[HIV = 1] * [DR = 0]	4.602	.359	12.821	.000	3.899	5.306
[HIV = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [DR = 0]	4.427	.161	27.478	.000	4.111	4.743
[MT = 0] * [DR = 1]	7.194	.388	18.560	.000	6.435	7.954
[MT = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [HIV = 0]	-.654	.166	-3.929	.000	-.980	-.328
[MT = 0] * [HIV = 1]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 0]	0[a]	.	.	.	.	.
[MT = 1] * [HIV = 1]	0[a]	.	.	.	.	.
[MT = 0]	0[a]	.	.	.	.	.
[MT = 1]	0[a]	.	.	.	.	.
[HIV = 0]	0[a]	.	.	.	.	.
[HIV = 1]	0[a]	.	.	.	.	.
[DR = 0]	0[a]	.	.	.	.	.
[DR = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + HIV * DR + MT * DR + MT * HIV + MT + HIV + DR

Appendix 17 Step Summary of MT, TB and PN

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*TB*PN	.000	0	.	
	Deleted Effect	1	MT*TB*PN	10.679	1	.001	3
1	Generating Class[b]		MT*TB*PN	.000	0	.	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 18 Parameter Estimates MT, TB and PN

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	.916	.632	1.449	.147	-.323	2.156
[MT = 0]	6.403	.633	10.115	.000	5.162	7.643
[MT = 1]	0[a]	.	.	.	.	.
[TB = 0]	1.099	.730	1.504	.132	-.333	2.530
[TB = 1]	0[a]	.	.	.	.	.
[PN = 0]	1.099	.730	1.504	.132	-.333	2.530
[PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 0] * [PN = 0]	.282	1.367	.206	.837	-2.396	2.960
[MT = 0] * [TB = 0] * [PN = 1]	.403	.731	.551	.581	-1.029	1.835
[MT = 0] * [TB = 1] * [PN = 0]	.565	.731	.773	.440	-.868	1.997
[MT = 0] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0] * [PN = 0]	3.301	.817	4.038	.000	1.698	4.903
[MT = 1] * [TB = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [PN = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + MT + TB + PN + MT * TB * PN

Appendix 19 Step Summary of MT, TB and DR

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*TB*DR	.000	0	.	
	Deleted Effect	1	MT*TB*DR	4.051	1	.044	2
1	Generating Class[b]		MT*TB*DR	.000	0	.	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 20 Parameter Estimates OF MT, TB and DR

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	.405	.816	.497	.619	-1.195	2.005
[MT = 0]	6.502	.817	7.959	.000	4.901	8.103
[MT = 1]	0[a]	.	.	.	.	.
[TB = 0]	1.609	.894	1.800	.072	-.143	3.362
[TB = 1]	0[a]	.	.	.	.	.
[DR = 0]	1.735	.885	1.959	.050	-.001	3.470
[DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [TB = 0] * [DR = 0]	-.349	1.708	-.204	.838	-3.697	2.999
[MT = 0] * [TB = 0] * [DR = 1]	-.043	.895	-.048	.962	-1.797	1.712
[MT = 0] * [TB = 1] * [DR = 0]	.402	.886	.454	.650	-1.334	2.139
[MT = 0] * [TB = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 0] * [DR = 0]	2.665	.959	2.780	.005	.786	4.544
[MT = 1] * [TB = 0] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [TB = 1] * [DR = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.
b. Model: Poisson
c. Design: Constant + MT + TB + DR + MT * TB * DR

Appendix 21 Step Summary Of MT, PN and DR

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		MT*DR*PN	.000	0	.	
	Deleted Effect	1	MT*DR*PN	.196	1	.658	2
1	Generating Class[b]		MT*DR, MT*PN, DR*PN	.196	1	.658	
	Deleted Effect	1	MT*DR	176.726	1	.000	2
		2	MT*PN	276.758	1	.000	2
		3	DR*PN	26.329	1	.000	2
2	Generating Class[b]		MT*DR, MT*PN, DR*PN	0.196	1	0.658	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Appendix 22 Parameter Estimates of MT, PN and DR

Parameter	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Constant	-2.335	.486	-4.804	.000	-3.287	-1.382
[MT = 0]	9.465	.485	19.507	.000	8.514	10.416
[MT = 1]	0[a]	.	.	.	.	.
[DR = 0]	4.521	.357	12.647	.000	3.821	5.222
[DR = 1]	0[a]	.	.	.	.	.
[PN = 0]	4.402	.338	13.043	.000	3.741	5.064
[PN = 1]	0[a]	.	.	.	.	.
[MT = 0] * [DR = 0]	-2.793	.356	-7.842	.000	-3.491	-2.095
[MT = 0] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 0]	0[a]	.	.	.	.	.
[MT = 1] * [DR = 1]	0[a]	.	.	.	.	.
[PN = 0] * [DR = 0]	-.176	.035	-5.074	.000	-.245	-.108
[PN = 0] * [DR = 1]	0[a]	.	.	.	.	.
[PN = 1] * [DR = 0]	0[a]	.	.	.	.	.
[PN = 1] * [DR = 1]	0[a]	.	.	.	.	.
[MT = 0] * [PN = 0]	-3.112	.336	-9.260	.000	-3.770	-2.453
[MT = 0] * [PN = 1]	0[a]	.	.	.	.	.
[MT = 1] * [PN = 0]	0[a]	.	.	.	.	.
[MT = 1] * [PN = 1]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

b. Model: Poisson

c. Design: Constant + MT + DR + PN + MT * DR + PN * DR + MT * PN