

**USING VCT DATA AS AN ALTERNATIVE TOOL
FOR TREND ANALYSIS AND MONITORING OF
HIV/AIDS EPIDEMIC AND ITS DEMOGRAPHIC
IMPACT IN ADDIS ABABA, ETHIOPIA**

By:

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**Using VCT Data as an Alternative Tool for Trend Analysis and
Monitoring of HIV/AIDS Epidemic and its Demographic Impact
in Addis Ababa, Ethiopia**

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Acronyms and Abbreviations

AAU	Addis Ababa University
AGR	Annual Growth Rate
AIDS	Acquired Immunodeficiency Syndrome
AIM	AIDS Impact Model
ANC	Antenatal Care
ART	Antiretroviral Therapy
ARV	Antiretroviral
ASFR	Age-Specific Fertility Rate
CDC	U.S. Centers for Disease Control and Prevention
CDR	Crude Death Rate
CSA	Central Statistical Authority of Ethiopia
DHS	Demographic and Health Surveys
EPP	Estimation and Projection Package
HAPCO	HIV/AIDS Prevention and Control Office
HIV	Human Immunodeficiency Virus
IMR	Infant Mortality Rate
MOH	Ministry of Health
NGO	Non-Governmental Organization
PLWHA	People Living With HIV/AIDS
TFR	Total Fertility Rate
U5MR	Under-5 Mortality Rate
UN	United Nations
UNAIDS	Joint United Nations Program on HIV/AIDS
VCT	Voluntary Counseling and Testing
WHO	World Health Organization

Abstract

A retrospective quantitative study was carried out from January to June 2006, to know the magnitude and trend of HIV/AIDS epidemic in Addis Ababa using data from the routine VCT services as an alternative data source and thereby to determine its impact on selected demographic variables.

Based on the large sample size (481,648 VCT clients in Addis Ababa) taken inference was made to estimate the prevalence of HIV/AIDS for the entire Addis Ababa. Accordingly, the VCT based modeled prevalence curve depicts three epidemic patterns that show a gradual increment at the start of the HIV epidemic followed by a rapid rise to a peak and rapid fall in HIV prevalence with a subsequent slowing down in the pace of the HIV prevalence.

In this study, both ANC and VCT modeled prevalence rates showed similar and regular trend from the beginning of the HIV epidemic till the year 1995 where the modeled ANC data showed higher prevalence rates. However, a lower HIV prevalence was noted for the ANC than the VCT modeled data during the years of 1996 through 2002. On the contrary, the ANC modeled prevalence was higher than the VCT prevalence starting from 2004 onwards where a maximum difference of 2.2 percent was observed towards the end of the projection period.

This study suggests that VCT modeled HIV prevalence data closely approximate prevalence among all ANC attendees in Addis Ababa setting where very high participation rate exists to the routine VCT services.

Based on the two sets of data sources and the corresponding HIV prevalence obtained, the study shows that, in the absence of AIDS, the two major mortality indicators namely: IMR and U5MR decline over the projection period. The presence of HIV/AIDS epidemic, however, slows down this decline, and in fact reverses it in some cases like CDR and LE at birth.

Although ANC based surveillance system provides solid long-term data, the rapid expansion of routine VCT program in an urban setting like Addis Ababa can be considered as an alternative data source to replace or supplement the ANC based surveillance, where a population based sero-prevalence survey is less likely to be conducted at regular intervals to monitor the HIV/AIDS epidemic trend.

1. Introduction

Acquired Immunodeficiency Syndrome (AIDS) is caused by a Human Immunodeficiency Virus (HIV) that weakens the immune system, making the body susceptible and unable to recover from other diseases. The HIV/AIDS epidemic has become a serious health and development problem in many countries around the world.

AIDS has killed more than 25 million people since it was first recognized in 1981, making it one of the most destructive epidemic in recorded history. The Joint United Nations Program on HIV/AIDS (UNAIDS) estimates the total number of people living HIV (PLWHA) reached its highest level: an estimated 40.3 million [36.7 - 45.3 million] people are now living with the virus. Close to 5 million people were newly infected with HIV in 2005, (UNAIDS/WHO, 2005).

The rapid expansion of HIV/AIDS in Sub-Saharan countries has a profound impact on the health sector as well as the socio-economic development of the region in general. According to the same report, Sub-Saharan Africa remains hardest-hit, and is home to 25.8 million [23.8 - 28.9 million] people living with HIV. Almost two third of all people living with HIV are in Sub-Saharan Africa, (UNAIDS/WHO, 2005).

The first evidence of HIV infection in Ethiopia was recognized in the early 1980's. The first two AIDS cases were reported in 1986. Since then, the disease has spread at an alarming rate. Currently, the Country is home to the third largest HIV infected population next to India and South Africa. The HIV/AIDS epidemic is a threat to the development of Ethiopia. A total of 1.59 million people were estimated to be living with HIV/AIDS in the year 2004. It was also estimated that there were a total of 244,000 new HIV infections in 2004. For the same year, it is estimated that there were a total of 133,000 new AIDS cases. Among children, it is estimated that there were a total of 104,000 children living with HIV/AIDS, 37,500 new HIV infections, 27,000 new AIDS cases and 27,000 deaths in the year 2004. A

total of 4.6 million all-cause orphans are estimated for Ethiopia in 2003, of which 539,000 of them being AIDS orphans. The estimated adult prevalence rate in the year 2003 is 4.4 percent (urban 12.6% and rural 2.6%). The estimated prevalence among females was 5 percent in 2003 whereas among men it was 3.8 percent, (MOH: *Technical Document*, 2004).

Addis Ababa is the capital city of the Federal Democratic Republic of Ethiopia and it is the major urban center of the country. According to CSA report, the projected Addis Ababa population for the year 2005 was 2.9 million of which 1.4 million were males and 1.5 million were females. Much of the population growth in the city still stems from migration from the countryside and smaller urban areas (CSA, 1999).

Addis Ababa is reported to have one of the highest concentrations of HIV/AIDS cases in the country. According to surveillance reports of the Ministry of Health, the HIV/AIDS prevalence rate for Addis Ababa is estimated to be 14.6 percent and 14.5 percent in the years 2003 and 2004, respectively. A total of 241,000 and 246,000 people were estimated to be living with HIV/AIDS in the years 2003 and 2004, respectively. It was also estimated for Addis Ababa that there were a total of 28,000 and 29,000 new HIV infections in 2003 and 2004, respectively. Approximately, 23,000 people died of AIDS in Addis Ababa in each of 2003 and 2004. Women in the age group of 25-29 years and men in the age group of 30-34 years show the highest prevalence of HIV in 2003, (MOH: *Technical Document*, 2004).

Since early 1980s when AIDS was first recognized there has been uncertainty about the future trend and the ultimate dimensions of this pandemic. This uncertainty persists because of difficulties in measuring HIV incidence and prevalence with a substantial degree of precision in a given population. Among the many one of the major factor for the lack of precision in measuring the HIV incidence and prevalence is the problem of obtaining representative data sources (that can be fed into the appropriate computer packages) that can be extrapolated to the general population.

In Ethiopia the prevalence of HIV among pregnant women attending Antenatal Clinics (ANC), after some adjustments, is applied to all adults to get a national and regional estimate of people living with HIV/AIDS. That is, in order to obtain the HIV prevalence curve overtime (that best fits all available data points) both at the regional and national levels, the ANC based HIV prevalence values will be fed into the *EPP* (Estimation and Projection Package) software. Further, the EPP-based prevalence estimates and projections will be fed into the *Spectrum* computer program. This computer program provides estimates for parameters such as AIDS cases and deaths, HIV-positive births, orphan and other related estimates based on ANC data source.

However, in regions like Addis Ababa where the majority of HIV infections are concentrated within populations whose behavior puts them at especially high risk of contracting and passing on the virus, estimates and projections based on prevalence among women at ANC may be less precise. That is, ANC-based estimates will miss a significant part of the epidemic.

Furthermore, some types of heterosexually driven epidemics are not well captured by ANC-based estimates. Antenatal-based estimates assumes that HIV infection is spread relatively equally between men and women in the general population. However, there are cases (regions/countries) where a relatively large number of male clients buy sex from a relatively small number of female sex workers leading to more men to be infected than women.

In addition, sex workers are usually more likely than other women to be infertile or to be using contraceptives. This means that estimates based on HIV infection in pregnant women will not accurately reflect the true level of HIV infection in regions/countries where the epidemics is driven largely by commercial sex between men and women.

2. Literature Review

In December 2005, an estimated 40.3 million adults and children world wide were living with HIV/AIDS, and close to 5 million (12.4% of the total HIV prevalence) people were newly infected with the virus in 2005. Since AIDS was first recognized in 1981, it has killed more than 25 million people, making it one of the most destructive epidemics in recorded history. Two thirds (25.8 million) of all people living with HIV are living in Sub-Saharan Africa, (UNAIDS/WHO, 2005).

According to the recent reports of MOH, the prevalence rate of HIV in Ethiopia is estimated to be 4.4 percent in 2003 and 4.6 percent in 2004. Among the urban population the prevalence is estimated to be 12.6 percent in 2003 and 12.5 percent in 2004. Among the rural population the corresponding estimates are 2.6 percent in 2003 and 2.8 percent in 2004. The prevalence figures are calculated to be higher among women (5.0%) than men (3.8%). The estimated adult incidence of HIV was 0.68 percent in 2003 and 0.67 percent in 2004. According to the same report, the incidence of HIV is remaining fairly constant in the subsequent years to come. As per the report mentioned earlier, in Ethiopia the urban epidemic seems to stabilize after around 2001/02, where as the rural epidemic shows a rising trend resulting in the total national trend to be increasing, (MOH: *Technical Document*, 2004).

In Ethiopia, a total of 1.47 million and 1.59 million persons were estimated to be living with HIV/AIDS in the year 2003 and 2004, respectively. It is also estimated that there were a total of 231,000 and 244,000 new HIV infections in 2003 and 2004, respectively. In the same year, it is estimated that there were a total of 123,000 and 133,000 new AIDS cases. The corresponding figures for the annual AIDS deaths were 115,000 and 124,000. Among children, it is estimated that there were a total of 96,000 and 104,000 children living with HIV, there were 34,900 and 37,500 new HIV infections, 25,000 and 27,000 new AIDS

cases and correspondingly, there were 25,000 and 27,000 deaths, in 2003 and 2004, respectively, (MOH: *Technical Document*, 2004).

HIV prevalence among ANC attendees continues to be a good approximation of HIV prevalence in the general population. In several countries recent estimates of national prevalence, based on ANC surveillance data, have been lower than estimates in earlier years, coinciding with an extension of the surveillance system to rural areas. In most cases there has not been a real decline in prevalence, but the lower prevalence is due to the prior under representation of rural areas in the surveillance system. For example in Ethiopia, national prevalence was estimated at 6.4 percent in 2001 but only 4.4 percent in 2003. However, the epidemic in Ethiopia is likely to still be expanding because of prevalence increases in rural areas, where almost 85 percent of the population resides. Therefore, the apparent decline in national prevalence is an artifact due to the more representative ANC surveillance system in 2003. To avoid this bias, analyses of HIV prevalence trends in ANC sites should be restricted to those sites with consistent reporting over time, (Ghys, Kufa and George, 2006).

The strength of ANC lies in the absence of selection bias and the availability of individual data. Conversely, the quantity of VCT data often exceed those in ANC, but may be subject to bias due to self-selection or test refusal. When using VCT data for surveillance, investigators must consider these caveats, as well as their varying data quality, accessibility, and availability of individual records. A study in Uganda comparing prevalence trends among VCT clients and ANC attendees has shown that although the prevalence was higher in VCT, the overall trends in prevalence were similar, (Baryarama et al., 2004).

Between 2001 and 2003, more ANC sites in Ethiopia showed a decline than a rise in HIV prevalence, but most lacked statistical significance. Modeled data suggested a rise in prevalence of HIV in rural areas (2003: 2.6%) and in all Ethiopia (2003: 4.4%), but a stable

or declining prevalence in Addis Ababa (2003: 14.6%) and other urban areas (2003: 11.8%). The total burden of HIV/AIDS is expected also to rise substantially due to population growth. In Addis Ababa, crude data on HIV prevalence from ANC too suggested a falling trend. VCT data from 2002 to 2004 supported this trend but indicated a mixed trend pattern for high risk behavior (Hladik et al., 2006).

The most direct impact of AIDS is an increase in the number of deaths in the affected population. Because of high HIV prevalence in Sub-Saharan Africa, the estimated crude death rate for 2005 is already considerably higher for most countries because of AIDS. In Botswana, Kenya, Namibia, South Africa, and Haiti, crude death rates would be expected to be in the single digits without AIDS but are in double digits with AIDS. In South Africa, for example, the crude death rate in 2005 is estimated to be 21 per 1,000 population with AIDS versus 7 per 1,000 population without AIDS; in Botswana the crude death rate is estimated to be 29 per 1,000 population with AIDS versus 3.5 per 1,000 without AIDS, (Laura et al., 2004).

With the HIV epidemic still growing in many countries, and in light of the long time lag between infection and death, HIV related mortality is projected to continue to increase in many countries over the coming years. This means that the adverse impact of HIV/AIDS on society and the economy is likely to worsen. Estimated HIV prevalence is declining in Kenya and Uganda, and as a result the increase in crude death rates due to AIDS mortality will be considerably reduced in the next decade. Crude death rates are projected to decline from 15 per 1,000 population to 8.5 per 1,000 population for Kenya and 13 per 1,000 population to 9 per 1,000 population for Uganda by 2015, (Laura et al., 2004).

In 2005, in the 15 selected countries, HIV/AIDS is estimated to have increased deaths among adults by 1.5 million. Even countries with low estimated prevalence, where mortality due to other causes may be lower, are estimated to experience increases in deaths

among the adult population. A dramatic rise will be seen among those countries with estimated adult HIV prevalence rates over 30 percent, such as Botswana, where HIV/AIDS is estimated to increase crude death rates among adults by over 30 per 1,000 population, (Laura et al., 2004).

The relative impact of HIV/AIDS on infant mortality will depend on the prevalence of the epidemic in the population, in addition to infant mortality from other causes. Unfortunately, because of the AIDS pandemic, much of the decrease in infant mortality seen during the 1980s and 1990s has disappeared. In Sub-Saharan Africa over 30 percent of all children born to HIV infected mothers become HIV-positive through the birth process or by breastfeeding.

It is estimated that in 2005 more infants are likely to die from HIV/AIDS than from any other cause in Botswana and Namibia. With an HIV prevalence of nearly 40 percent, Botswana has an estimated infant mortality rate of 55 infant deaths per 1,000 live births in 2005; it would be 14 per 1,000 live births in the absence of AIDS. Namibia's estimated infant mortality rate is 49 infant deaths per 1,000 live births, an increase of 26 infant deaths per 1,000 due to AIDS. Estimated infant mortality in South Africa is increased by 40 percent as a result of AIDS. Both Kenya and Uganda are experiencing only slightly increased estimated infant mortality rates as well, and, because of their efforts against the HIV/AIDS epidemic, infant mortality by 2015 is projected to decrease by 17 and 16 births, respectively, with increases of 1 death and 2 deaths per 1,000 live births due to AIDS, (Laura et al., 2004).

Many HIV-infected children survive past their first birthday only to die before the age of five. AIDS deaths among children under-5 are resulting in higher mortality rates in that age group. Under-5 mortality is estimated to have more than doubled because of HIV/AIDS in Namibia; in Botswana 80 percent of deaths among children under-5 are due to HIV/AIDS;

and 40 percent of under-5 mortality in South Africa is due to HIV/AIDS. HIV/AIDS will also aggravate under-5 mortality rates in countries such as Côte d'Ivoire, Ethiopia, Mozambique, Nigeria, Rwanda, Tanzania, Uganda, Zambia, and Haiti, which already have high under-5 mortality rates due to other causes. By 2015 HIV/AIDS mortality is estimated to make up nearly 90 percent of deaths in this age group in Botswana, two-thirds of deaths in Namibia, and half of deaths in South Africa, (Laura et al., 2004).

Countries reporting stabilizations or declines in HIV sero-prevalence are still likely to experience amplified adult crude death rates due to infections before 10 years. Zambia has estimated adult crude death rate of 19 deaths per 1,000 adults in 2005, a tripling due to HIV/AIDS mortality. Rwanda and Kenya have estimated crude death rates of 10.5 and 10 per 1,000 adults, an increase of 6 per 1,000. Even with the decline in prevalence levels in Uganda, death rates there are still inflated by 4 per 1,000 adults as a result of HIV/AIDS, to a rate of 9 deaths per 1,000 adults. In the absence of HIV/AIDS, by 2015 the percentage of all deaths projected to occur in adults would likely remain stable; however, with HIV/AIDS mortality an increase in the adult percentage of deaths is projected for many of the countries selected. In Côte d'Ivoire, Mozambique, South Africa, Tanzania, Zambia, and Haiti, 40 to 50 percent of all deaths are projected to occur in the adult population. In Botswana and Namibia, over 60 percent of all deaths are likely to occur among adults, (Laura et al., 2004).

Ever since AIDS was recognized as a critical global health problem that would lead to increased adult and child mortality there have been debates about the demographic impact of HIV/AIDS. There have been speculations that the impact of HIV/AIDS might be so large as to cause negative population growth rates in some countries. Much of this debate has centered on Central Africa, where HIV prevalence rates are the highest. Anderson et al. concludes that in the most affected areas HIV/AIDS is likely to change population growth rates from positive to negative, (Anderson et al., 1991).

A study by Bongaarts found that the population growth rates are unlikely to turn to negative in Central Africa. More likely, the population growth rates in central Africa will not drop below half of their current values (Bongaarts, 1990).

According to the report on technical meeting of UNAIDS and UN Population Division, the effect of HIV/AIDS epidemic on population size is more striking in the nine most affected African countries. In 1995, their population stood at 119 million, 1.3 million (1.1%) less than it would have been without AIDS. Furthermore, since the impact of the epidemic is projected to increase, the estimated difference between the projected population with and without AIDS, in relative terms, is 7.8 percent in 2005 and rises to 14.6 percent in 2015. At the country level, by 2015, the populations of Botswana and Namibia are expected to be 20 percent lower than they would have been in the absence of AIDS and Zimbabwe's population will be 19 percent lower. In South Africa, a country facing one of the most rapidly rising epidemics, the population is expected to be 16 percent lower than in the absence of AIDS. In other countries where adult HIV prevalence is already above 10 percent, the population in 2015 is also expected to be significantly lower because of HIV/AIDS (UNAIDS & UN Population Division, 1998).

Although HIV/AIDS has a very serious relative effect on population size in the long run, none of the countries considered shows a decline in population size during the projection period. Even in the countries with the highest HIV prevalence, the population is expected to be nearly one and half times as high in 2015 as in 1985, (UNAIDS & UN Population Division, 1998).

The remarkably high population growth expected in African countries in spite of the HIV epidemic is primarily due to the persistence of high fertility in most of the region. Even in a low fertility country, such as Thailand, the population is expected to continue growing under the impact of HIV/AIDS, though overall growth will be 24 percent between 1995

and 2015 rather than the 26 percent estimated in the absence of the epidemic (UNAIDS & UN Population Division, 1998).

Population will continue to grow in most of the African countries, even though estimated crude death rates are high, because of high fertility. However, populations in severely affected countries are projected to decline over time, as is evident in Botswana, where the estimated 2005 growth rate was negative, (Laura et al., 2004).

In addition, population growth rates in Namibia and Zambia for 2005 were estimated to be half or less of what they would have been without AIDS. By 2015, in addition to Botswana and South Africa, Guyana and Namibia are projected to experience negative or zero population growth rates because of HIV/AIDS mortality compounded by lower fertility and international migration. Generally, as a direct consequence of lower population growth rates, populations will be much smaller in the future than they would have been in the absence of HIV/AIDS in many of the affected countries, (Laura et al., 2004).

According to Ministry of Health report, the total population of Ethiopia lost due to HIV epidemic was about 0.9 million in 2003 and will reach 1.8 million by 2008. Though HIV/AIDS will have a significant impact on population size, the population of Ethiopia was estimated to increase by 2.014 million and 2.064 million in the years 2004 and 2005, respectively. By 2008 it is estimated to increase by 2.199 million. The same report has also revealed that, in the presence of HIV epidemic the annual population of Addis Ababa increases by 62.93 and 66.44 thousand in the years 2006 and 2008, respectively, (MOH: *Technical Document*, 2004).

In developing countries life expectancy was chronically low mainly because of high infant mortality. Once measures were taken to alleviate the common causes of infant mortality, life expectancies began to climb. However, life expectancies in many Sub-Saharan African countries are now estimated to be cut in half because of HIV/AIDS mortality among adults.

For Botswana, Namibia, and South Africa, with the estimated adult HIV prevalence over 20 percent, expectation of life at birth are estimated to have lost 24 to 42 years as a result of HIV/AIDS mortality, (Laura et al., 2004).

In the presence of HIV/AIDS mortality, life expectancy in Haiti is 53 years instead of 61 years; in Guyana life expectancy is 65.5 years instead of 70 years. Mortality is expected to continue to result in lower life expectancies in Latin America, the Caribbean, and Asia. Life expectancies in 2015 are projected to be 5 and 8 years lower in Guyana and Haiti, respectively, than they would be without AIDS, (Laura et al., 2004).

Gregson et al. (1997) have examined the question of the impact of HIV/AIDS on fertility by examining potential changes in the proximate determinants of fertility (Gregson, 1994; Gregson et al., 1997). They concluded that the most likely result is that an HIV epidemic will slightly reduce fertility without indicating clear evidence. A study in Tanzania found weak evidence that adult mortality due to HIV/AIDS leads to reduced fertility rates, (Ainsworth, Filmer and Semali, 1995).

Two studies in Uganda indicate that HIV-infected women had lower fertility rates than HIV-negative women. One of these, in rural Rakai district (Gray et al., 1997), shows that age-specific fertility rates (ASFR) for HIV-infected women were 50 percent less than those for women who were not infected. Another study among a rural population in Masaka (Carpenter et al., 1997), found that fertility rates were 20 to 30 percent lower among HIV-infected women. Since most women did not know their sero-status, the reason for less fertility rates was most likely due to biological rather than behavioral factors. The finding suggests that fertility might be 20 to 50 percent lower among HIV-infected women. In societies with substantial use of contraception, there might be a reduction in contraceptive use that would partially compensate for this effect. Fertility among young women who are HIV-positive is likely to be higher than for all women, since all HIV-positive women are sexually active but not all young women are sexually active.

Since the 1950s, mortality has been declining in the more developed countries as well as in the developing countries. Life expectancy at birth in the world as a whole has increased and in many parts of the world, populations have started enjoying the benefits of longevity. However, since the appearance of the HIV/AIDS pandemic in the late 1970s and early 1980s, the gains in longevity so painfully achieved in many developing countries, in particular those in Sub-Saharan Africa, are in serious jeopardy.

In some urban centers of Sub-Saharan Africa and Western Europe, HIV/AIDS has already become the leading cause of death for both men and women aged between 15 and 49. AIDS kills people in their most productive years and ranks as the leading cause of potentially healthy life years lost in Sub-Saharan Africa, (World Bank, 1993).

At the beginning of the third decade of the global pandemic, HIV/AIDS has reversed gains in life expectancy and improvements in child mortality in many countries; mortality among the population aged 15-49 has increased many fold, even in countries with modest epidemics, (Laura et al., 2004).

For Thailand, a country with an estimated adult HIV prevalence rate of “only” 1.5 percent the World Health Organization (WHO) estimates that the crude mortality rate for those aged 15-49 years almost doubled from 2.8 to 5.4 per 1,000 between 1987 and 1996, (WHO, 2004).

In Sub-Saharan Africa, a region of the world most severely affected by HIV/AIDS, the increase in mortality due to HIV/AIDS is already a significant demographic event, effectively negating earlier progress made in such key human development indicators as infant mortality and life expectancy, (Laura et al., 2004).

3. Problem Statement and Rationale of the Study

Sentinel surveillance systems that provide data on HIV prevalence among clients of antenatal clinics (ANC) were not originally designed to develop national estimates of HIV prevalence or to monitor the epidemic by estimating HIV incidence. Nevertheless, in many countries these are the best data available for those purposes.

Surveillance data referring to the clients of antenatal clinics were judged to be the cornerstone for the derivation of national estimates of HIV prevalence in countries with generalized epidemics and were likely to remain so in the near future. Although those data appeared to reflect reasonably well the situation among adult women of reproductive age, there were a number of factors that could affect their representativeness. In particular, researchers emphasized the need to understand better the effects of HIV infection on fertility and the biases these effects may cause in antenatal clinic data.

ANC-based estimates assume that HIV infection is spread relatively equally between men and women in the general population. However, there are cases where a relatively large number of male clients buy sex from a relatively small number of female sex workers resulting in more men to be infected than men.

In addition, sex workers are usually more likely than other women to be infertile or to be using contraceptives. This means that estimates based on HIV infection in pregnant women will not accurately reflect the true level of HIV infection in regions/countries where the epidemics is driven largely by commercial sex between men and women.

Researchers have recognized that current United Nations estimates and projections of HIV prevalence and, consequently, of the demographic impact of the epidemic represent only one plausible scenario regarding the evolution of the epidemic. It was recommended that in preparing a new set of projections, two or three scenarios about the future course of the epidemic could be considered.

Researchers have also called for a review of the design of sentinel surveillance systems to explore ways in which they might be improved so as to produce data that would be more adequate for estimating HIV incidence and prevalence at the national level.

In regions like Addis Ababa where the majority of HIV infections are concentrated within populations whose behavior puts them at especially high risk of contracting and passing on the virus, estimates and projections based on prevalence among women at ANC may be less precise. That is, antenatal-based estimates will miss a significant part of the epidemic.

To this end, one has to search for a data source that best represents the general population as compared to the currently implemented ANC data source and thereby to have relatively more accurate HIV/AIDS estimates and projections in the country in general and the capital city Addis Ababa in particular. The availability of such precise estimates and projections was thought essential in aiding decision-makers to understand the magnitude of the HIV/AIDS problem and in supporting efforts to improve prevention and health-care programs.

Since the 1950s, mortality has been declining in both developed and developing countries. Life expectancy has been increasing and impressive gains have been made in reducing infant and child mortality. Recently, however, HIV/AIDS has caused a reversal of these trends in the most severely affected countries, particularly in Sub-Saharan Africa. It is estimated by UNAIDS and WHO that more than 40 million people have been infected with HIV since the beginning of the epidemic and 13 million have progressed to AIDS.

Beginning with the 1992 Revision, the Population Division of the United Nations Secretariat has made explicit allowance for the potential demographic impact of AIDS in preparing the population estimates and projections of countries where the epidemic has reached significant proportions.

HIV/AIDS projections can illustrate the magnitude of the AIDS epidemic and the demographic, social and economic consequences. This illustration also can show policymakers the impacts on other areas of development and the size of the impacts that could be expected without effective action. HIV/AIDS projections are also needed to plan the response.

Projecting the future demographic impact of HIV/AIDS requires a sound methodology for projecting the number of future HIV infections and for determining the impact of those infections on the future pattern of adult and child deaths.

The scarcity of direct information about HIV prevalence among men was also identified as a major source of uncertainty in the estimates for many countries including Ethiopia. For the few countries that had information on prevalence among both men and women, there was no consistent pattern of differences between the sexes. In some countries men exhibited higher prevalence while in others women had higher prevalence levels. In countries affected by more generalized epidemics, women did tend to show higher prevalence than men. A systematic effort to gather information leading to estimates of HIV prevalence among men was thought necessary.

Given the uncertainty surrounding many of the assumptions made in both estimating and projecting the course of the epidemic, it will be advisable to explore for other complementary data sources such as the VCT data, since the future course of the epidemic depends significantly on its current state.

National and regional HIV estimates for Ethiopia are derived from modeling serial ANC based HIV prevalence data. Alternative data source has not been exhaustively explored for being a potential tool to monitor the trend of HIV/AIDS epidemic in the country.

It has been observed that there is a growing trend and positive attitude towards the VCT services in the capital city for which the number of VCT centers had been scaled-up with the objective of meeting this increasing demand. The current large number of VCT centers and relatively unbiased VCT clients (and data on both sexes) in Addis Ababa will be positive factors in searching for a data source that best represents the general population in the capital city.

To this end, there are few or no information available regarding the HIV/AIDS estimation, projection and its demographic impact using prevalence data from VCT centers in the capital city. In light of the recommendations made by the UNAIDS technical group, to undertake research on other data source for a better estimates and projections, the investigator intends to explore for consistency/disparity of findings obtained from ANC sentinel sites and VCT centers that enrolled quite sufficient number of subjects in Addis Ababa.

4. Objectives of the Study

4.1. General Objective:

To know the magnitude and trend of HIV/AIDS epidemic in Addis Ababa using data from the routine VCT services as an alternative data source that could potentially be used as a tool to monitor the trend of HIV/AIDS and thereby, determine its impact on selected demographic variables such as mortality, life expectancy, population size and growth.

4.2. Specific Objectives:

To:

- ✚ Estimate the adult HIV prevalence rate for Addis Ababa using VCT as a primary data source and make comparison with the routine ANC data source.
- ✚ Detect disparity or consistency in the trend of adult HIV prevalence rate as documented by the MOH AIDS Update, in view of proving or disproving the potential benefit of using VCT data source in monitoring the trend of HIV/AIDS epidemic in an urban setting.
- ✚ Determine the scope of similarities or discrepancies between two sets of data sources (ANC and VCT) in assessing the magnitude of HIV/AIDS pandemic by estimating and projecting HIV/AIDS prevalence using EPP computer package in Addis Ababa, Ethiopia.
- ✚ Assess and compare the impact of HIV/AIDS on:
 - Major mortality indicators (Infant Mortality Rate, Under-5 Mortality Rate, Crude Death Rate and Expectation of Life at Birth);
 - Population size;
 - Annual growth rate and population doubling time using VCT and ANC data sources separately, overtime using Spectrum computer program in two scenarios with and without AIDS in Addis Ababa, Ethiopia.

5. Study Methodology

5.1. Study Area:

This study was conducted in Addis Ababa, the capital city of Ethiopia. The capital city is structured into 10 sub-cities and 99 kebeles, the lowest level of administration of the city. According to Central Statistical Authority (CSA) of Ethiopia report on July 2005, the population of Addis Ababa was estimated to be 2.9 million of which 1.4 million (48.04%) were males and 1.5 million (51.6%) were females, (CSA, 1999). The majority of its total population (73.4%) of about 2.9 million people is aged between 15 and 49 years (35% between 15 and 24 years). The city is reported to have an annual growth rate of 2.82 percent, mostly due to migration from rural to urban. The total fertility rate was found to be 2.24, the estimated infant mortality rate was 78 deaths per year per 1000 live births and the estimated expectation of life at birth was 58 years (57 years for males, 60 years for females). The health service coverage for Addis Ababa is 87 percent. There are 28 hospitals (5 regional, 13 private and 10 federal hospitals) and 27 health centers. A total of 508 clinics are rendering health services in the capital.

Addis Ababa is reported to have one of the highest concentrations of HIV/AIDS in the country. According to recent surveillance reports of the Ministry of Health, the modeled HIV prevalence rate in Addis Ababa amounts to be 14.6 percent and 14.5 percent, with a number of people living with HIV/AIDS that was increasing (241.27 and 245.93 thousand) for the years 2003 and 2004, respectively. Women in the age group of 25-29 years and men in the age group of 30-34 years show the highest prevalence of HIV in the year 2003. In the beginning of 2006, almost 57 percent of the hospital beds in the city are occupied by AIDS patients (MOH: *Technical Document*, 2004).

5.2. Study Design and Data Collection:

This retrospective quantitative study was carried out from January to June 2006. For estimating and projecting HIV prevalence rates in Addis Ababa and thereby to assess its demographic impact, this study uses secondary data which were collected from all government, private and NGO VCT centers, where the HIV status of more than 480,000 clients were entered during the period of 2003 to 2005 in Addis Ababa, (Annex II: Table II.2). In order to have a better estimate each VCT centers were categorized to sub-city level before entering to EPP.

For the purpose of making comparative analysis of the VCT based estimated and projected prevalence values and demographic variables with that of the commonly used ANC based estimation and projection, ANC clinic site prevalence values for a period 1989 to 2003 were collected from all five sentinel sites in Addis Ababa, (Annex II: Table II.1).

5.3. Data Analysis:

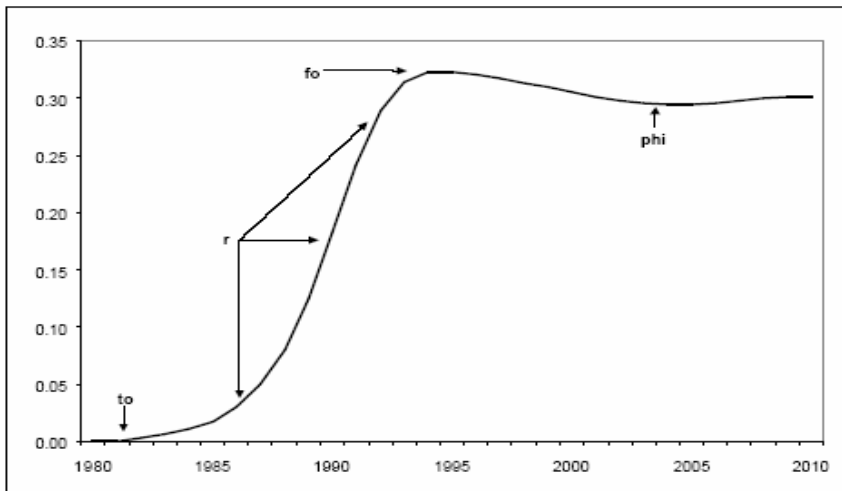
The estimates and projection on HIV prevalence curves using ANC data and VCT data were obtained through the use of Estimation & Projection Package (EPP) computer software.

EPP is a simple epidemiological model that produces the basic epidemic curve shapes found in most HIV epidemics. EPP initially divides the population into two parts, those who are *not at risk* of HIV infection and those who are *at risk*. People would not be *at risk* if they are not sexually active, if they have only one partner who has no outside partners, or if they successfully use condoms all the time otherwise they are categorized in *at risk* group. New entrants are children reaching the age of fifteen. They can enter either of the population groups. Some of those who are *at risk* will become infected and progress to AIDS death. All population groups are subject to the risk of dying from causes other than HIV/AIDS.

The dynamics of EPP model are described by four parameters namely, the *start year of the HIV epidemic* (t_0) in which an earlier start year will cause the curve to rise earlier & a later

start year will produce a curve that starts later, *initial proportion of at risk population* (f_0) that determines the peak of the epidemic curve, *the force of infection* (r) which governs the rate at which people in the susceptible population become infected and *the distribution of new entrants to not at risk and at risk categories* (Φ) that determines the amount of decline in prevalence after it reaches a peak.

Figure 1: Parameters that Determines the Shape of the Epidemic Curve in EPP



The EPP model is described as follows:

The population *not at risk* (X) is increased by new entrants and reduced by non-AIDS deaths

$$(\mu X): \frac{dX}{dt} = [1 - f(X/N)].E_t - \mu X$$

The population at risk (Z) is increased by new entrants and reduced by non-AIDS deaths and

$$\text{new HIV infections } (rY/N): \frac{dZ}{dt} = f(X/N).E_t - (\mu + rY/N + I).Z$$

The infected population (Y) is increased by new infections (rY/N and I) and decreased by

$$\text{progression to AIDS death: } \frac{dY}{dt} = (rY/N + I).Z - \int_0^t (rY_x/N_x + I_x).Z_x.g(t-x)dx$$

Where:

Z = *At risk* population, Y = Infected Population

X = *Not at risk* population, $N = X + Y + Z$

μ = the Non-AIDS death rate

$$l = \begin{cases} 1 & \text{for the first year of the epidemic} \\ 0 & \text{for other years} \end{cases}$$

g = function describing the proportion progressing to AIDS death by the number of years since HIV infection

The fraction of those individuals entering the adult population (E_t) who enter the *at risk* group (Z) $f(X/N)$ is given by:

$$f(X/N) = \frac{\exp\left[\phi\left(\frac{X}{N} - (1 - f_o)\right)\right]}{\exp\left[\phi\left(\frac{X}{N} - (1 - f_o)\right)\right] + \frac{1}{f_o} - 1}$$

The function $f(X/N)$ determines the proportion of new entrants to the adult population that enter the at risk population. EPP uses this model to find prevalence curves that fit available surveillance data.

Finally, EPP searches for the best values of the four remaining parameters t_o , f_o , r and Φ . The best parameter values are those that produce the prevalence curve which best fits the surveillance data. The best fit is determined by minimizing the sum of the squared errors, the differences between the model curve and the surveillance estimates in each year, (See methodology of EPP presented in Annex IV.1).

Separate EPP files namely; ANC based and VCT based were constructed for each of the ANC and VCT data sources. For both of the data sources, the epidemic in Addis Ababa was assumed to have started in 1982. The EPP curves that best fit the data points on the graph were taken to represent the HIV prevalence for the respective data sources in Addis Ababa.

Finally, EPP provides the estimated and projected prevalence values for each ANC and VCT data sources from 1982 to 2010 in Addis Ababa.

The estimation and projection of prevalence using EPP is then followed by determination of the demographic impact of the epidemic on Addis Ababa population based on the extent of HIV prevalence obtained from ANC and VCT data sources. A comparative analysis of the two data sources was also made with AIDS and without AIDS scenarios to know the scope of the epidemic impact on selected demographic variables. With AIDS scenario shows what has happened and what is projected to happen in Addis Ababa because of HIV/AIDS mortality and its demographic consequences. However, without AIDS scenario shows a hypothetical series of what the modeling work indicates would have happened if the capital city had not been affected by the HIV/AIDS epidemic. This modeling takes into account not only lower death rates but also associated changes to the age-sex structure and, indirectly, the combined effects of lower mortality and changing population composition on demographic indicators.

The Spectrum software package was used to estimate the demographic consequences of HIV/AIDS and other estimates using ANC and VCT data sources separately in Addis Ababa with and without AIDS scenarios. Three separate Spectrum files namely; Spectrum file without AIDS, ANC based Spectrum file with AIDS and VCT based Spectrum file with AIDS were constructed for the purpose of undertaking comparative analysis of the demographic impact of HIV/AIDS under different scenarios overtime. For this purpose, AIM (AIDS Impact Model) which is part of Spectrum was applied. Before applying AIM it is necessary to undertake population projections for Addis Ababa which is prepared using DemProj, a component of Spectrum computer program, (See methodology of Spectrum presented in Annex IV.2).

5.3.1. Demographic Projections:

The major inputs used to prepare the Addis Ababa population size figure were obtained from the official census results published by the Central Statistical Authority (CSA), report entitled “*The 1994 Population and Housing Census of Ethiopia, Results for Addis Ababa, Volume II Analytical Report*”. The following information has been used for the population projections:

- Population age distribution by sex for the year 1995 (Annex III: Table III.2).
- Total fertility rates (TFR), expectation of life at birth and percent urban for the years 1995-2010, (Annex III: Table III.1).

Projection inputs for the period 1982-1995 were mainly based on the 1994 census results. The census fertility and life expectancy levels for the years 1995-2000 were assumed to apply to the period 1982-1995. The yearly change in the percentage urban during 1995-2000 that was reported in the census was also applied for 1982-1995 period. Other projection inputs were: sex ratio at birth of 103; an age specific fertility equal to the UN Sub-Saharan pattern; and the Coale-Demeny West model of mortality. The official census projection inputs and their results all referred to mid years of the projection periods. Consequently, the projection results in this study also refer to mid years.

The census report used 1995 as the base year. However, the base year in this study is the start year of the epidemic in Addis Ababa which was assumed to be 1982. Because of this, 1982 has to be used as the base year for the projection. Thus, it was necessary to obtain Addis Ababa's population size figures for the year 1982. The census population size figures of 1995 were therefore back projected to obtain 1982 figures. The back projection was prepared by using 1995 population size figures and applying the negative growth rates which is 4.4 percent reported by the census for the years 1995-2000 in Addis Ababa, (Annex III: Table III.2). Therefore, the projection in this research uses the back projected 1982 figures as a base year population, and provides projection results for the period up to 2010. DemProj population programs were prepared to provide projected population size figures for the period 1982-2010. Three separate DemProj files namely; DemProj file without AIDS, DemProj file ANC based with AIDS and DemProj file VCT based file with AIDS were prepared. Finally, the new DemProj files prepared (the one without AIDS) for Addis Ababa was checked to see whether it provided similar population figures mentioned for 1995 in the census report.

5.3.2. HIV/AIDS Related Estimates:

As indicated above, the projections in this study uses the Spectrum computer program, which uses the AIM component together with DemProj. The AIM component allows the input of HIV related information, and provides various HIV-related outputs. The AIM program was constructed separately for the three different cases mentioned earlier.

The projection inputs utilized by AIM were: EPP resulted HIV prevalence values separately for the two data sources and zero prevalences for the without AIDS scenario; HIV progression rate; HIV age distribution; perinatal transmission rate; TFR reduction due to HIV; percent infants with HIV dying in first year; and life expectancy after AIDS onset. The AIM program provides assumed rates for all the above; and these rates were assumed to apply for the projection in this study, (Annex III: Table III.3). The Spectrum program in this study also assumes that no significant number of HIV-positive persons receive ARV inputs, this is appropriate for regions like Addis Ababa where only a fraction (<10%) of all eligible HIV-positive persons actually receive ARVs.

6. Results

6.1: Estimated and Projected Adult HIV Prevalence Using ANC & VCT Data Sources, 1982-2010, in Addis Ababa

The estimates on HIV prevalence were obtained through the use of EPP (Estimation and Projection Package) Program. Separate EPP files were constructed for each ANC and VCT data sources. In both cases, the epidemic in Addis Ababa assumed to have started in 1982. The EPP curves that best fit the points on the graph were taken to represent the HIV prevalence for each data source in Addis Ababa. Then EPP supplied prevalence estimates for each of the different data sources from 1982 to 2010.

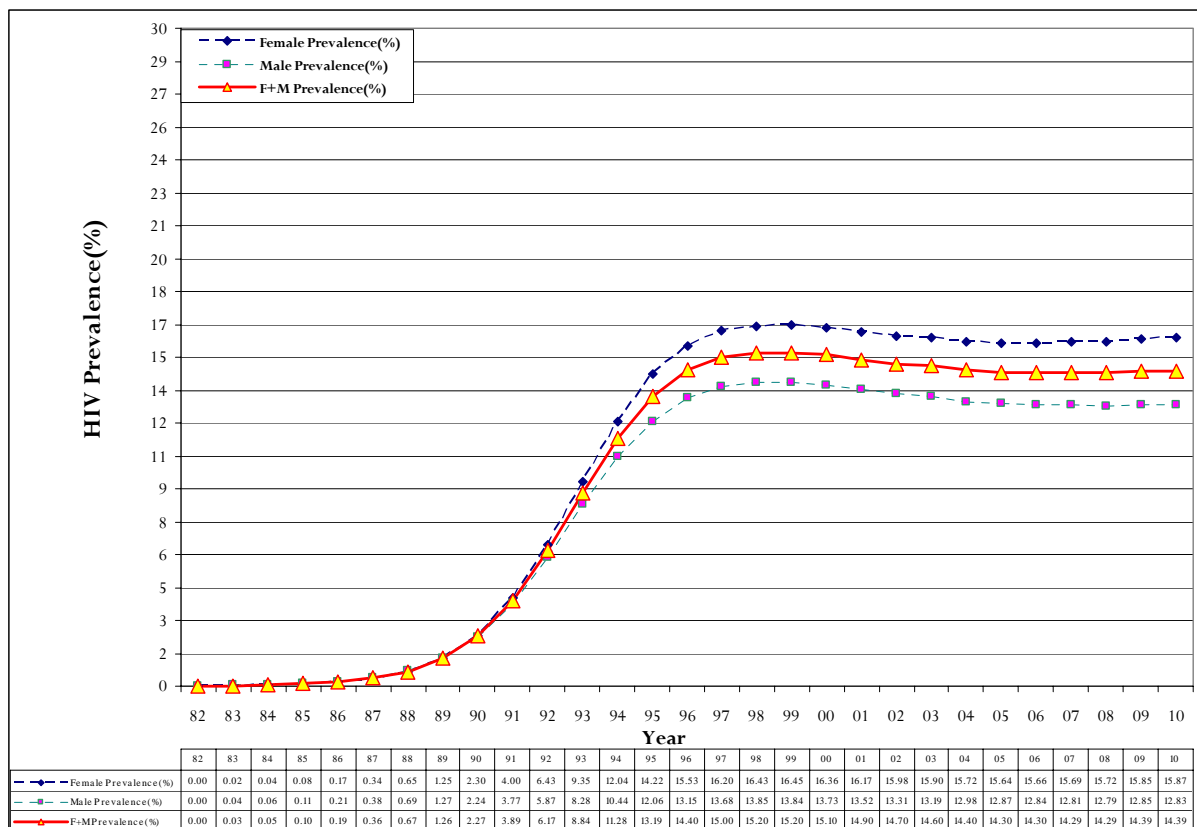
Note that, throughout this paper, the term *estimate* is used to refer those year(s) value(s) where actual modeled data are used. For example, the ANC based prevalence values for the years 1989 to 2003, where actual site prevalence data were used, termed as estimated prevalence values. Whereas the term *projected* is used to refer those year(s) value(s) that are extrapolated based on the actual sample data employed in the study. That is, in the case of the above example, prevalence values for the years 1982-1988 and 2004-2010 are referred as projected prevalence values.

6.1.1: Estimated and Projected Adult HIV Prevalence using ANC Data, 1982-2010, in Addis Ababa

ANC clinic prevalence data from all five ANC sentinel sites for a period of 1989 to 2003 was used for the purpose of estimating HIV prevalence in Addis Ababa. The ANC based HIV prevalence values, except for the years 2004 and 2005 which was not released by MOH, were fed into the EPP software and then EPP models the prevalence data for the given years and suggests an HIV prevalence curve over time (1982-2010) that best fits all available data points (Figure 2).

As illustrated in the figure below, there was a gradual rise in HIV prevalence between the period of 1983 (0.03%) to 1989 (1.26%). From 1989 a fast increment in prevalence had been observed and this persisted till the year 1997 (15%) and has reached a peak of 15.20 percent in the years of 1998 and 1999. The adult HIV prevalence curve started showing a declined trend from 2000 (15.1%) to 2004 (14.4%) followed by a stability period during the years of 2005 through 2008 with a prevalence rate of 14.3 percent. A slight rise and stability of HIV prevalence (14.4%) is also noted for the years 2009 and 2010. The epidemic curve has also demonstrated a higher HIV prevalence for women than men from the year 1990 onwards. The trend of the HIV epidemic from 1982 to 2010 suggests three epidemic patterns namely, a gradual rise at the start of the epidemic, followed by a rapid increment and a declining phase with a subsequent stability period.

Figure 2: Estimated and Projected ANC Based Adult HIV prevalence by Sex, 1982-2010, in Addis Ababa



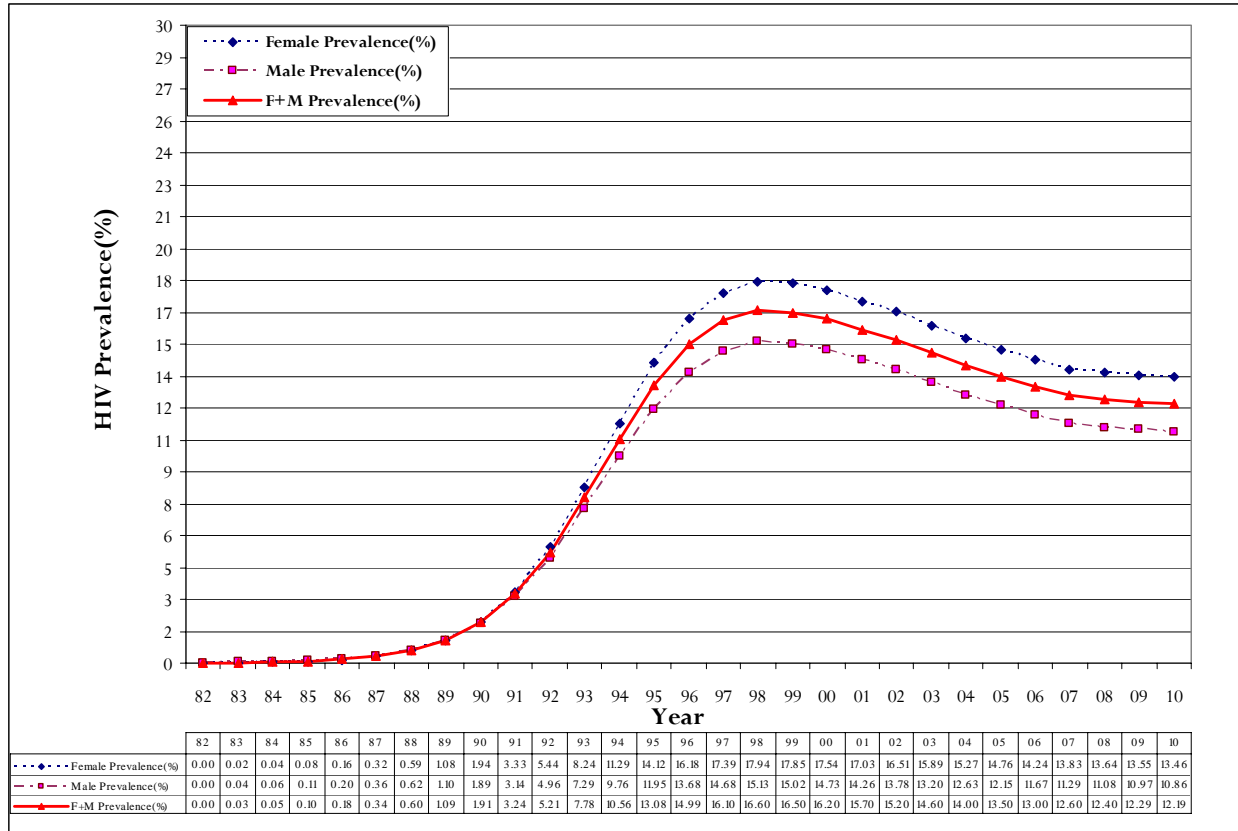
6.1.2: Estimated and Projected Adult HIV Prevalence using VCT Data, 1982-2010, in Addis Ababa

For estimating & projecting VCT based HIV prevalence, three years (2003-2005) prevalence data were collected from all government, private & NGO VCT centers rendering routine VCT services in Addis Ababa. Individual centers were categorized and aggregated to sub-city level in order to feed the EPP for a better estimate (Annex 2: Table 2.2). The EPP curve that best fits all sub-city based prevalence data points were taken as the VCT based prevalence levels for the entire Addis Ababa (Figure 3).

A total of 481,648 VCT clients of which 57.5 percent females were checked in all government, private and NGO health facilities during the three years period and their HIV status determined using standard tests (139,714 in 2003, 183,591 in 2004 and 158,343 in 2005 three quarters). The proportion of clients who got VCT services from the private, government and NGOs accounts for 47 percent, 35 percent and 18 percent, respectively. Based on the large sample size taken for each year from 2003-2005, inference was made to estimate the HIV prevalence for the entire Addis Ababa (see Figure 3). Accordingly, the estimated adult HIV prevalence for Addis Ababa using VCT centers has shown a gradual rise in HIV prevalence between the period of 1983 (0.03%) to 1990 (1.91%). Starting from 1990 a fast increment in prevalence had been observed that persisted till the year 1997 (16.1%) and has reached a peak of 16.6 percent in the year 1998.

The adult HIV prevalence curve started showing a rapidly declining trend from 1999 (16.5%) to 2008 (12.4%) followed by a very slow paced decline during the years of 2009 and 2010 with a prevalence rate of 12.29 and 12.19 percent, respectively. Similar to the ANC based modeled prevalence, the epidemic curve also shows a higher HIV prevalence for women than men from 1990 onwards. In summary the VCT based modeled prevalence curve depicts three epidemic patterns that show a gradual increment at the start of the HIV epidemic followed by a rapid rise to a peak and rapid fall in HIV prevalence with a subsequent slowing down in the pace of the HIV prevalence.

Figure 3: Estimated and Projected VCT Based Adult HIV Prevalence by Sex, 1982- 2010, in Addis Ababa



6.1.3: Variation between ANC and VCT Based Estimated and Projected HIV Prevalence, 1982-2010, in Addis Ababa

Figure 4: Estimated and Projected Adult HIV Prevalence Using ANC and VCT Data Sources, 1982-2010, in Addis Ababa

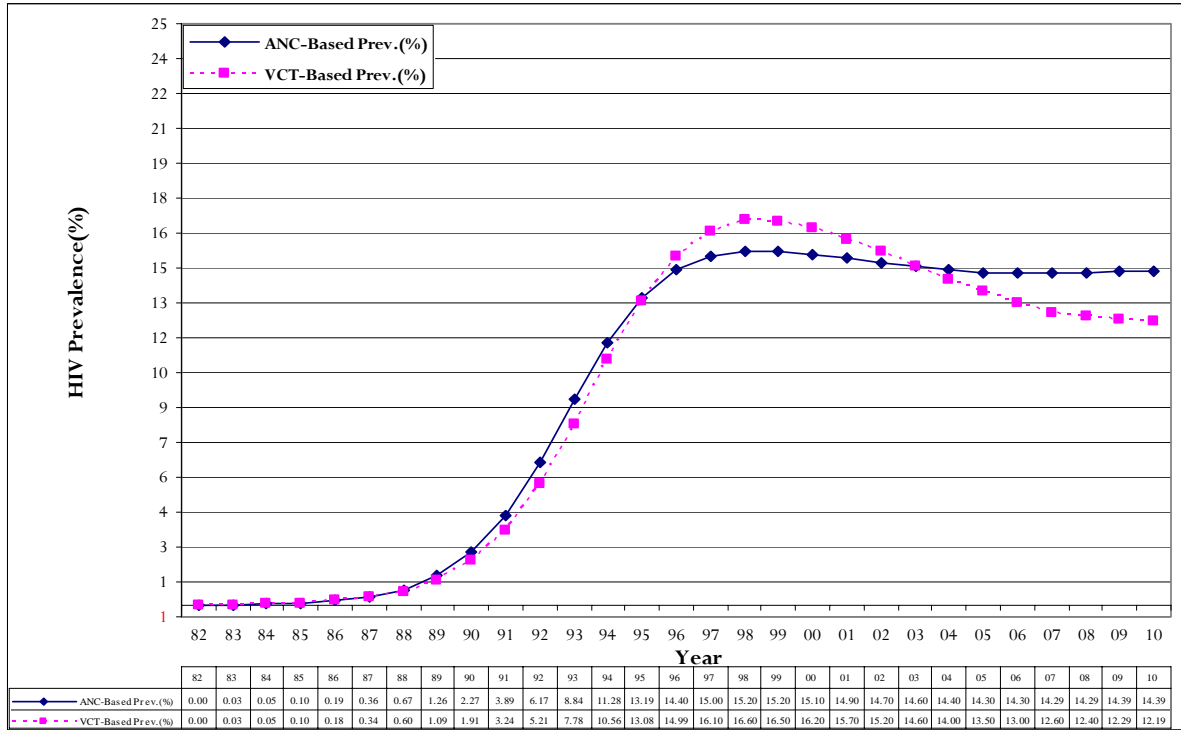
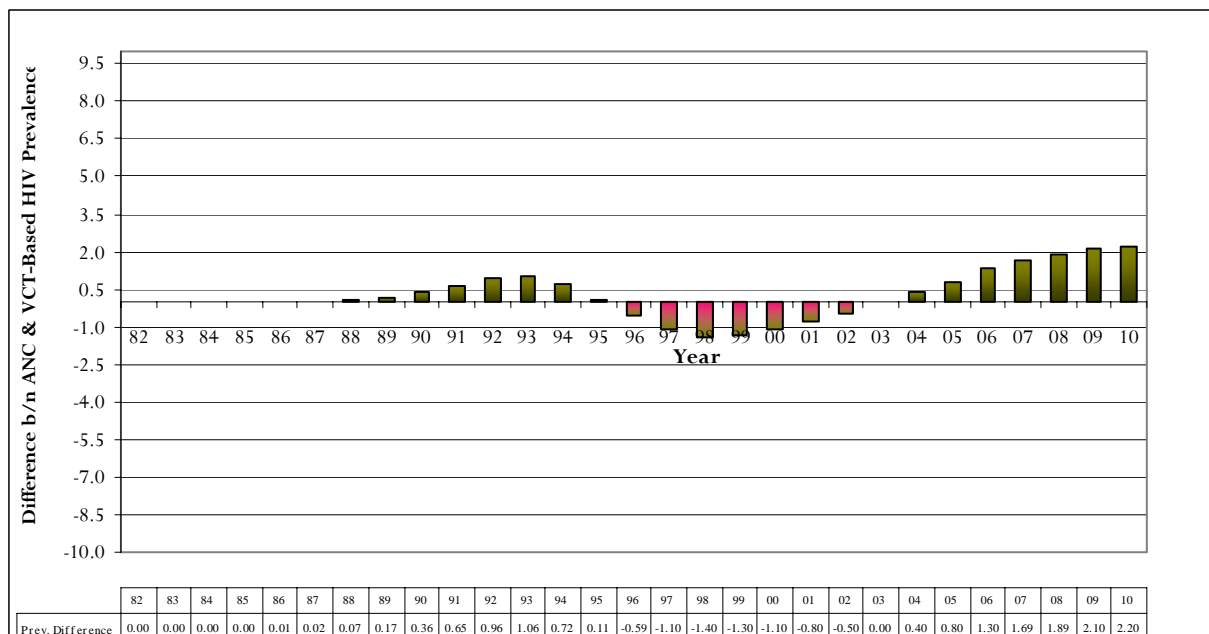


Figure 5: Difference between Estimated and Projected Adult HIV Prevalence Using ANC & VCT Data Sources, 1982-2010, in Addis Ababa



As indicated in Figures 4 and 5 above, both ANC and VCT modeled prevalence rate had a similar and regular trend at the beginning of the HIV epidemic till the year 1995. In 1995 the modeled ANC data showed a higher prevalence value than the VCT modeled one. The maximum difference in HIV prevalence was observed in 1993, the year when the ANC prevalence was 1.06 percent more than the VCT modeled prevalence. However, a higher HIV prevalence was noted for the VCT than the ANC modeled data during the years of 1996 through 2002 with a maximum difference of 1.4 percent lower for ANC modeled data than the VCT in 1998. The result also revealed that both the ANC and VCT modeled HIV prevalence reached the highest level during same period (1998) but with a difference in the extent and magnitude of the epidemic where the VCT modeled prevalence was much higher than that of the ANC modeled prevalence. On the contrary, the ANC modeled prevalence was higher than the VCT prevalence starting from 2004 onwards where a maximum difference of 2.2 percent was observed towards the end of the projection period. There is a consistent rise in the difference between ANC and VCT projected prevalence as the projection period increases (Figure 5).

6.2: Demographic Impact of HIV/AIDS in Addis Ababa Using ANC and VCT Data Sources, 1995-2010

In order to assess the demographic impact of HIV/AIDS for Addis Ababa using ANC and VCT data sources separately, major mortality indicators (such as infant mortality rate, under-5 mortality rate, additional deaths due to AIDS, crude death rate, and life expectancy at birth), total population size, annual population growth, and population doubling time in the presence of AIDS are compared with those without AIDS scenario.

Similar to the pattern of the major projected demographic variable inputs (used while projecting the population of Addis Ababa and related parameters) presented in the 1994 census results for Addis Ababa, except for total population size all the demographic variables

analyzed under different scenarios in this study are also presented in a five years interval basis starting from the years 1995 to 2010 (i.e. 1995-2000, 2001-2005 and 2006-2010).

6.2.1: Impact of HIV/AIDS on Major Mortality Indicators Using ANC and VCT Data Sources With & Without AIDS, 1995-2010, in Addis Ababa

Under this section results pertinent to the potential impact of HIV/AIDS on major mortality indicators such as infant mortality rate, under-5 mortality rate, additional deaths due to AIDS, crude death rate, and life expectancy at birth will be summarized separately.

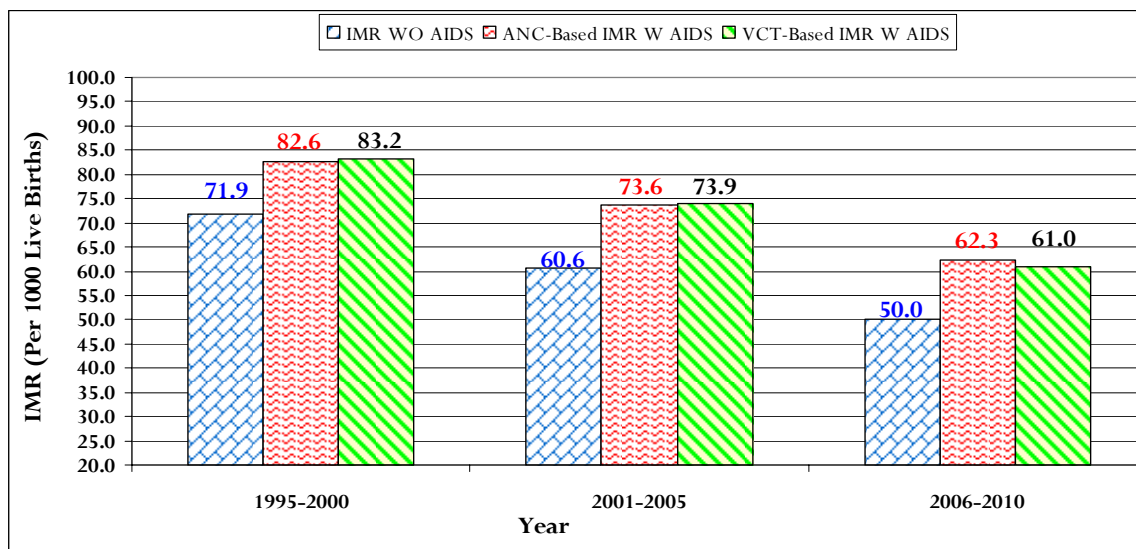
Table 1: Estimated and Projected Major Mortality Indicators (IMR, U5MR, CDR and LE) Using ANC & VCT Data Sources With and Without AIDS, 1995-2010, in Addis Ababa

Year	IMR (Per 1000 Live Births)			U5MR (Per 1000 Live Births)			CDR (Per 1000 Population)			Number of Deaths			Life Expectancy (Years)		
	Witho ut AIDS	With AIDS		Witho ut AIDS	With AIDS		Witho ut AIDS	With AIDS		Without AIDS	With AIDS		Witho ut AIDS	With AIDS	
		ANC Based	VCT Based		ANC Based	VCT Based		ANC Based	VCT Based		ANC Based	VCT Based		ANC Based	VCT Based
1995	71.9	81.5	81.5	100.5	113.7	113.3	8.9	11.4	11.1	19,122	24,503	23,883	59.7	54.0	54.5
1996	71.9	82.4	82.9	100.5	115.6	115.8	8.9	12.4	12.1	19,813	27,409	26,740	59.7	52.3	52.8
1997	71.9	82.9	83.7	100.5	116.8	117.6	8.9	13.4	13.1	20,496	30,584	29,976	59.7	50.7	51.1
1998	71.9	83.0	84.0	100.5	117.5	118.7	8.8	14.4	14.2	21,201	33,914	33,508	59.7	49.2	49.3
1999	71.9	83.0	84.0	100.5	117.8	119.2	8.9	15.4	15.4	21,927	37,194	37,090	59.7	47.8	47.8
2000	71.9	82.9	83.7	100.5	117.9	119.2	8.9	16.3	16.4	22,664	40,267	40,569	59.7	46.7	46.5
2001	60.6	71.5	72.1	82.7	99.6	100.7	7.9	16.0	16.3	20,850	40,575	41,273	62.1	47.6	47.2
2002	60.6	71.3	71.7	82.7	99.7	100.5	7.9	16.5	16.9	21,603	42,888	43,969	62.1	46.9	46.3
2003	60.6	71.3	71.3	82.7	99.5	99.9	8.0	16.9	17.4	22,424	44,793	46,140	62.1	46.5	45.9
2004	60.6	71.1	70.8	82.7	99.3	99.2	8.1	17.1	17.6	23,292	46,288	47,756	62.1	46.3	45.7
2005	60.6	71.1	70.5	82.7	99.1	98.6	8.1	17.1	17.7	24,202	47,466	48,816	62.1	46.3	45.7
2006	50.0	60.5	59.5	66.3	82.3	81.2	7.3	16.2	16.6	22,325	45,807	46,852	64.5	47.9	47.5
2007	50.0	60.5	59.2	66.3	82.5	80.9	7.4	16.1	16.3	23,283	46,614	47,169	64.5	48.0	47.8
2008	50.0	60.5	59.1	66.3	82.5	80.6	7.5	16.0	16.0	24,256	47,428	47,293	64.5	48.1	48.3
2009	50.0	60.5	59.0	66.3	82.6	80.4	7.5	15.9	15.7	25,267	48,288	47,366	64.5	48.3	48.9
2010	50.0	60.5	58.9	66.3	82.7	80.3	7.6	15.9	15.4	26,320	49,298	47,572	64.5	48.4	49.4

6.2.1.1: Impact of HIV/AIDS on Infant Mortality Rate (IMR)

The infant mortality rates (the estimated number of infants per 1,000 live births who will die before their first birthday) for Addis Ababa, both taking into account the impact of AIDS and in the absence of it using ANC and VCT data sources. Based on the ANC data, infant mortality in Addis Ababa is estimated to decline from 82.6 deaths of infants under age one per 1,000 live births in 1995-2000 to 62.3 per 1,000 in 2006-2010 during the HIV era. However in the absence of AIDS, the decline would have been much steeper, from 71.9 deaths per 1,000 live births to 50.0 per 1,000 live births (Figure 6). Infant mortality rate in the presence of AIDS during the period of 1995-2000 was higher by 14.8 percent than in the absence of AIDS. Infant mortality rate could have been lower by 19.7 percent for the projected period of 2006-2010 in the absence of HIV/AIDS epidemic.

Figure 6: Estimated and Projected IMR Using ANC & VCT Data With and Without AIDS, 1995-2010, in Addis Ababa



Similarly, the VCT data source indicates that there will be a decline in IMR from 83.2 deaths per 1000 live births during 1995-2000 to 61.0 in 2006-2010 which is a

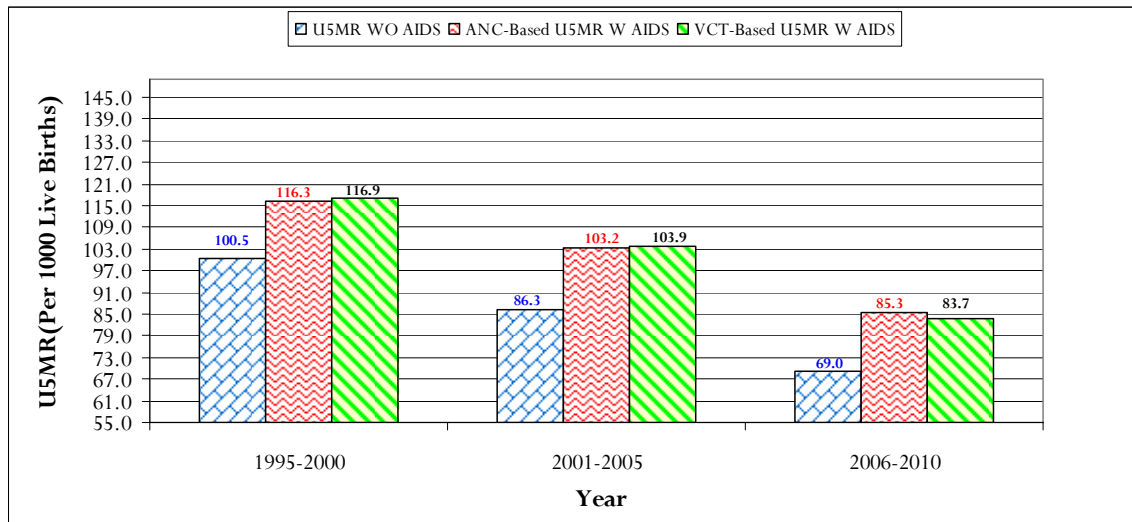
slightly higher projection (0.79%) as compared to the ANC data source. The infant mortality rate during the years of 2001-2005 was almost similar both for the ANC and VCT data. However, VCT data show that there were slightly less infant deaths during the period of 2006-2010 as compared to the ANC data for the same period.

6.2.1.2: Impact of HIV/AIDS on Under-5 Mortality Rate (U5MR)

As indicated in Figure 7 below, without AIDS scenario, U5MR (the number of deaths to children that are under the age of 5 per 1,000 live births during the year) is expected to decline from 100.5 per 1000 live births in 1995-2000 to 69.0 per 1000 live births in 2006-2010. However, based on ANC data with AIDS scenario, it is expected to decline from 116.3 per 1000 live births in 1995-2000 to 85.3 per 1000 live births in 2006-2010. Similarly, the VCT data source indicates that there will be a decline in U5MR from 116.9 deaths per 1000 live births during 1995-2000 to 83.7 in 2006-2010 which is a lower projection (1.9%) as compared to the ANC data source.

The under-5 mortality rate for the periods 1995-2000 to 2001-2005 was almost similar both for the ANC and VCT data. However, ANC data show that there were slightly more deaths of under-5 children during the projected period of 2006-2010 as compared to the VCT data for the same period.

Figure 7: Estimated and Projected U5MR Using ANC & VCT Data With and Without AIDS, 1995-2010, in Addis Ababa



6.2.1.3: Impact of HIV/AIDS on Number of Deaths

Figure 8 shows the projected number of deaths from 1995 to 2010 taking into account the impact of the HIV/AIDS epidemic using both the ANC and VCT data. Also shown are the projected numbers of deaths assuming that there is no such epidemic. The difference between the two values can be considered as an additional number of deaths due to AIDS (Figure 9). In the absence of AIDS, the total number of deaths is expected to increase from 102,559 in 1995-2000 to 145,653 in 2006-2010. However, with AIDS scenario using ANC data, the total number of deaths is expected to rise from 153,604 in 1995-2000 to 284,901 in 2006-2010, implying that the epidemic would induce almost 139,248 (or 48.88%) additional deaths in the period 2006-2010. In the presence of AIDS about 653,316 cumulative deaths are projected to occur between 1995 and 2010, about 294,271 people more than the death figure (359,045) that would have been expected in the absence of AIDS.

Similarly, the results obtained using VCT data reveal that the total number of deaths is expected to rise from 151,197 in 1995-2000 to 285,068 in 2006-2010, implying

that the epidemic would induce almost 139,415 (or 48.91%) additional deaths. In the presence of AIDS about 655,972 cumulative deaths are projected to occur between 1995 and 2010, about 296,927 people more than the death figure (359,045) that would have been expected in the absence of AIDS.

Figure 8: Estimated and Projected Total Number of Deaths Using ANC & VCT Data With and Without AIDS, 1995-2010, in Addis Ababa

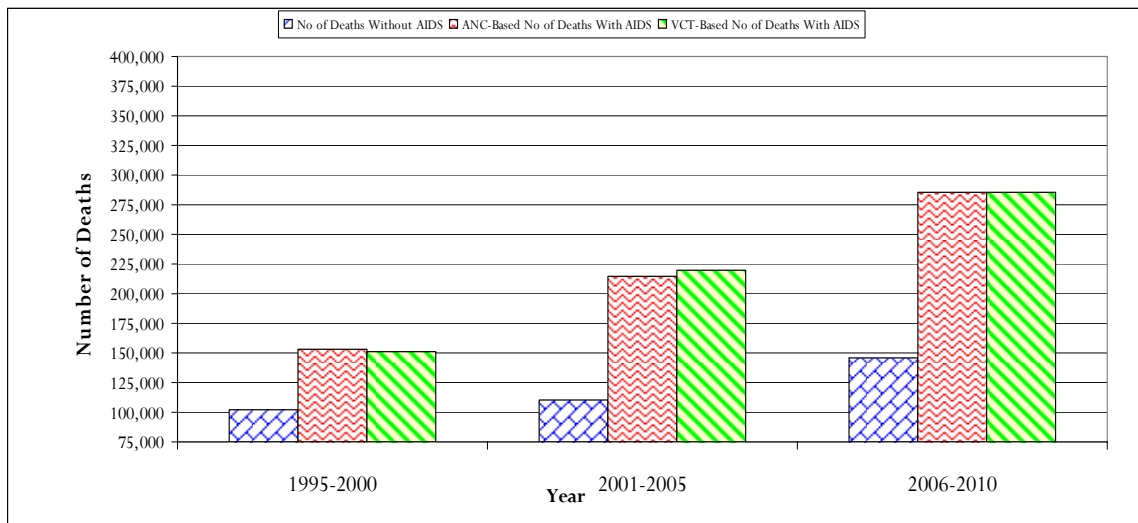
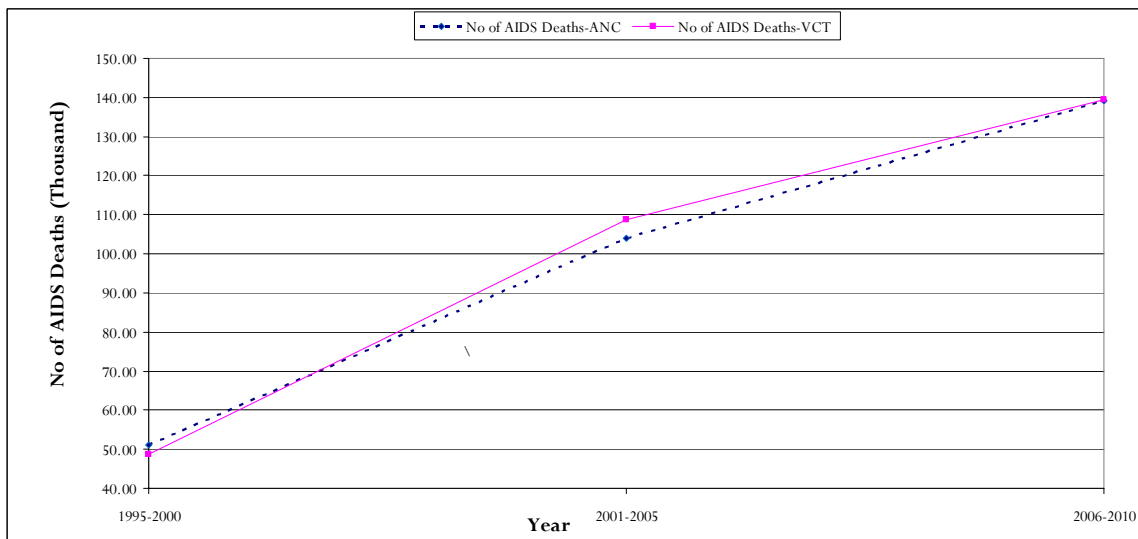


Figure 9: Estimated and Projected Number of AIDS Deaths Using ANC & VCT Data, 1995-2010, in Addis Ababa

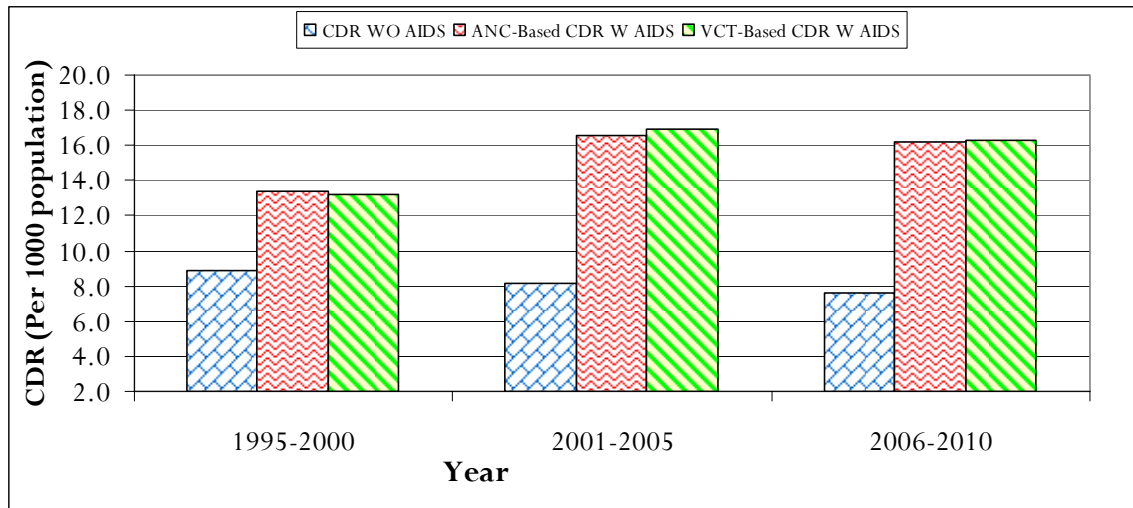


6.2.1.4: Impact of HIV/AIDS on Crude Death Rate (CDR)

Figure 10, below presents the average annual crude death rate (the number of deaths in a year per 1,000 of the mid-year population) for a five-year period, from 1995-2000 to 2006-2010, and for the two projections, with and without AIDS using ANC and VCT data. In the absence of AIDS, the crude death rate for Addis Ababa was expected to decline from 8.9 deaths per 1,000 persons in 1995-2000 to 7.6 deaths per 1,000 in 2006-2010. According to the ANC data source, AIDS was the reason for the increment of the crude death rate from 13.4 deaths per 1,000 in 1995-2000 to 16.2 deaths per 1,000 in 2006-2010. Similarly, VCT data shows an increase in the crude death rate from 13.2 per 1,000 in 1995-2000 to 16.3 deaths per 1000 in 2006-2010 which is attributed to the AIDS epidemic.

The crude death rate according to the projections with AIDS obtained from the projections without AIDS rose over time, attaining its maximum in 2001-2005 when AIDS was the cause for a 102.9 percent and 107.4 percent increase in the crude death rate as computed using the ANC and VCT data, respectively. At that period, the ANC and VCT based projected crude death rates were 16.6 and 16.9 deaths per 1,000 with AIDS, respectively. In without AIDS case the figure is 8.2 deaths per 1,000.

Figure 10: Estimated and Projected Crude Death Rate Using ANC & VCT Data With and Without AIDS, 1995-2010, in Addis Ababa



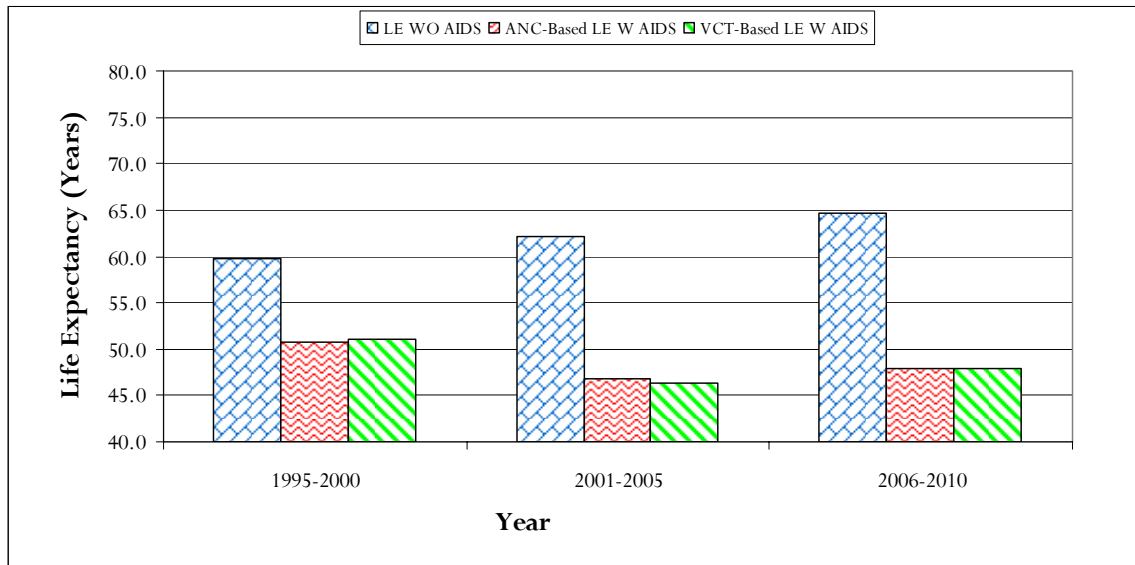
6.2.1.5: Impact of HIV/AIDS on Life Expectancy

Another consequence of HIV/AIDS epidemic is the reduction of life expectancy (the average number of years a person born in a given year can expect live) of the people. The graph below shows the change in life expectancy at birth with and without AIDS using two different data sources in Addis Ababa.

As shown in Figure 11 below, the life expectancy for Addis Ababa using the ANC data is estimated at 50.8 years in 1995-2000 instead of the 59.7 years it would have been in the absence of AIDS, a loss of nearly 9 years of life. By 2006-2010, the difference in expected life expectancy with and without AIDS is projected to be 16.8 years.

Similarly, the VCT data source reveals that there was an estimated difference of 16.7 years between life expectancy with and without HIV era for the projected period 2006-2010. Both the ANC and VCT data source indicate that, AIDS will be reason for the reduction of life expectancy by 17 years which is 26 percent reduction as compared to the absence of the epidemic by the year 2010.

Figure 11: Estimated and Projected Life Expectancy Using ANC & VCT Data With and Without AIDS, 1995-2010, in Addis Ababa



6.2.2: Impact of HIV/AIDS on Major Population Parameters Using ANC and VCT Data With and Without AIDS, 1995-2010, in Addis Ababa

Under this section results pertinent to the potential impact of HIV/AIDS on population parameters including population size, annual growth rate and population doubling time will be summarized separately.

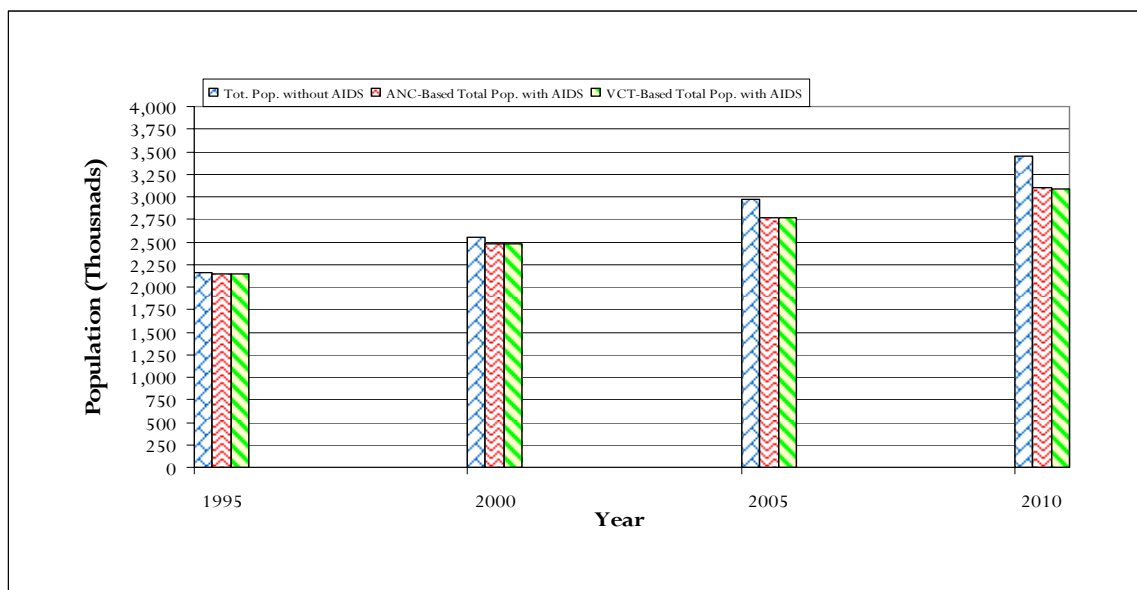
Table 2: Estimated and Projected Major Population Parameters (Total Population, AGR, and Doubling time) Using ANC and VCT Data With and Without AIDS, 1995-2010, in Addis Ababa

Year	Total Population (In Thousand)			AGR (Percent per Year)			Population Doubling Time (Year)		
	Without AIDS	With AIDS		Without AIDS	With AIDS		Without AIDS	With AIDS	
		ANC Based	VCT Based		ANC Based	VCT Based		ANC Based	VCT Based
1995	2,156.035	2,141.565	2,143.392	3.62	3.37	3.40	19.5	20.9	20.7
1996	2,235.923	2,213.362	2,215.923	3.49	3.16	3.19	20.2	22.3	22.1
1997	2,315.738	2,282.330	2,285.587	3.37	2.94	2.97	20.9	23.9	23.7
1998	2,395.627	2,348.418	2,352.181	3.26	2.74	2.75	21.6	25.7	25.5
1999	2,475.402	2,411.459	2,415.426	3.15	2.54	2.54	22.4	27.6	27.6
2000	2,554.896	2,471.473	2,475.221	3.04	2.35	2.34	23.1	29.8	29.9
2001	2,639.052	2,533.513	2,536.618	3.12	2.38	2.35	22.6	29.5	29.9
2002	2,722.696	2,593.054	2,595.090	3.00	2.22	2.18	23.4	31.5	32.1
2003	2,806.813	2,651.589	2,652.241	2.93	2.14	2.08	24.0	32.8	33.6
2004	2,891.504	2,709.714	2,708.814	2.86	2.07	2.01	24.6	33.8	34.8
2005	2,976.736	2,767.802	2,765.432	2.79	2.02	1.97	25.1	34.6	35.5
2006	3,068.359	2,831.598	2,828.035	2.92	2.18	2.14	24.1	32.1	32.7
2007	3,160.953	2,896.263	2,891.995	2.86	2.16	2.14	24.5	32.4	32.7
2008	3,254.408	2,961.715	2,957.454	2.81	2.14	2.14	25.0	32.7	32.7
2009	3,348.836	3,028.059	3,024.640	2.76	2.12	2.15	25.5	33.0	32.5
2010	3,444.345	3,095.280	3,093.580	2.71	2.10	2.16	25.9	33.3	32.4

6.2.2.1: Impact of HIV/AIDS on Population Size

Figure 12 below depicts the projected population size from 1995 to 2010 taking into account the demographic impact of HIV/AIDS using ANC and VCT data as well as the hypothetical projected population excluding the impact of HIV/AIDS. The absolute difference between the projected population with and without AIDS indicates the cumulative impact of HIV/AIDS. Based on the ANC data, the estimated population of Addis Ababa for the mid year 1995 is 2,141,565 about 14,470 people fewer (0.7% lower) than it would have been in the absence of AIDS. By 2010, the population is expected to be 3,095,280 indicating that there will be 349,065 (or 10.1%) less than it would have been in the absence of AIDS. Likewise, the estimated population of Addis Ababa using VCT data for the mid year 1995 is 2,143,392, about 12,643 people fewer (0.6% lower) than it would have been in the absence of AIDS. By the year 2010, the population is expected to be 3,093,580, about 350,765 people fewer (10.2% lower) less than it would have been in the absence of AIDS.

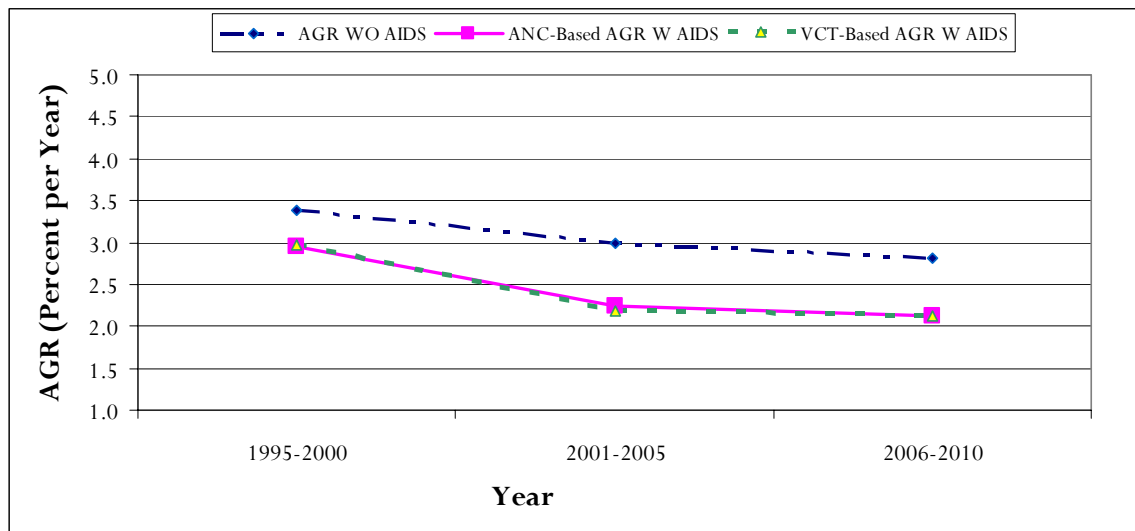
Figure 12: Estimated and Projected Total Population (Thousand) Using ANC and VCT Data With and Without AIDS, 1995-2010, in Addis Ababa



6.2.2.2: Impact of HIV/AIDS on Annual Population Growth Rate (AGR)

As shown in the following figure the annual growth rate (the rate at which the population is increasing or decreasing in a given year due to natural increase and net migration) was computed using the ANC and VCT data both in the AIDS and without AIDS scenario. Accordingly, the ANC data indicated that the growth rate which stood at 2.95 percent per year in 1995-2000 with AIDS scenario is expected to decrease by 28.1 percent to reach 2.12 percent per year during 2006-2010 as compared to the 16.9 percent decrease in annual growth rate in the absence of HIV/AIDS for the same period. Similarly, the AGR using VCT data declines from 2.97 percent per year in 1995-2000 to 2.12 (28.7% reduction) in the years 2006-2010. The data also showed that, in the absence of AIDS, Addis Ababa's population would have been growing at more than 2.8 percent per year in the year 2010.

Figure 13: Estimated and Projected Annual Population Growth Rate Using ANC and VCT Data With and Without AIDS, 1995-2010, in Addis Ababa

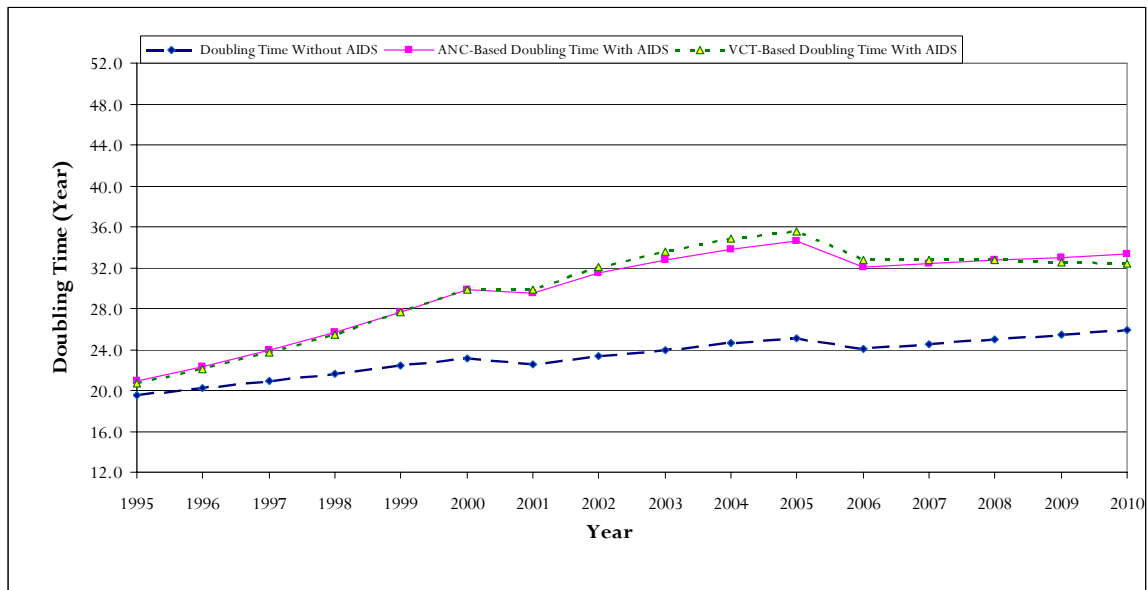


6.2.2.3: Impact of HIV/AIDS on Population Doubling Time

According to Figure 14 below, the population doubling time in the absence of AIDS increases from 20.92 years in the period 1995-2000 to 25.02 years in 2006-2010 (which is 8 years shorter than in the presence of AIDS using ANC data for the period 2006-10). In other words, as per the ANC data, the doubling time for the Addis Ababa population in the presence of AIDS epidemic increases from 24.08 years in the period 1995-2000 to 33.02 years in 2006-2010 (24.2% longer than in the absence of AIDS for the period 2006-2010).

A similar pattern is also observed using the VCT data while projecting the population doubling time, implying that HIV/AIDS epidemic has prolonged or delayed the doubling time by about 8 years in 2010.

Figure 14: Estimated and Projected Population Doubling Time Using ANC & VCT Data With and Without AIDS, 1995-2010, in Addis Ababa



7. Discussion

With the purpose of determining the magnitude of the HIV epidemic in Addis Ababa and thereby assess the impact of AIDS on selected demographic parameters, the investigator has used two sets of data sources, namely the popular ANC data and the newly emerging VCT data source. Accordingly, the ANC clinic prevalence data from all five ANC sentinel sites for a period of 1983 to 2003 were used for the purpose of estimating and projecting HIV prevalence in Addis Ababa. The ANC based HIV prevalence values, except for the years 2004 and 2005 which was not released by MOH, were fed into the EPP software to model the prevalence data for the given years and an HIV prevalence curve over time (1982-2010) that best fits all available data points.

This study revealed a gradual rise in HIV prevalence between the period of 1983 (0.03%) to 1989 (1.26%). From 1989 a fast increment in prevalence had been observed and this persisted till the year 1997 (15.0%) and has reached a peak of 15.20 percent in the years of 1998 and 1999. The adult HIV prevalence curve shows a declining trend from 2000 (15.1%) to 2004 (14.4%) followed by a stability period during the years of 2005 through 2008 with a prevalence rate of 14.3 percent. A slight rise and stability of HIV prevalence (14.4%) is also noted for the years 2009 and 2010. The epidemic curve has also demonstrated a higher HIV prevalence for women than men from the year 1990 onwards.

The trend of the HIV epidemic from 1982 to 2010 suggests three epidemic patterns namely, a gradual rise at the start of the epidemic, followed by a rapid increment and a declining phase with a subsequent stability period.

The overall pattern of the epidemic progression noted in this study is in conformity with the study conducted by the MOH in 2004 due to similarities in the assumptions made and identical data points considered from the five sentinel sites in Addis Ababa.

For estimating and projecting VCT based HIV prevalence, three years (2003-2005) prevalence data were collected from all government, private and NGO VCT centers rendering routine VCT services in Addis Ababa. Individual centers were categorized and aggregated to sub-city level in order to feed the EPP for a better estimate. The EPP curve that best fits all sub-city based prevalence data points were taken as the VCT based prevalence levels for the entire Addis Ababa.

Based on the large sample size taken for each year from 2003-2005, inference was made to estimate the HIV prevalence for the entire Addis Ababa using the VCT data source. Accordingly, the estimated adult HIV prevalence for Addis Ababa using VCT centers has shown a gradual rise in HIV prevalence between the period of 1983 (0.03%) to 1990 (1.91%). Starting from 1990 a fast increment in prevalence had been observed that persisted till the year 1997 (16.1%) and has reached a peak of 16.6 percent in the year 1998. The adult HIV prevalence curve has started showing a rapidly declining trend from 1999 (16.5%) to 2008 (12.4%) followed by a very slow paced decline during the years of 2009 and 2010 with a prevalence rate of 12.29 and 12.19 percent, respectively. Similar to the ANC based modeled prevalence, the VCT based epidemic curve also showed a higher HIV prevalence for women than men from 1990 onwards.

In summary, the VCT based modeled prevalence curve depicts three epidemic patterns that show a gradual increment at the start of the HIV epidemic followed by a rapid rise to a peak and rapid fall in HIV prevalence with a subsequent slowing down in the pace of the HIV prevalence.

This study has demonstrated a similar prevalence rate for the periods of 1982 to 1986, while a higher value was obtained during the years of 1987-1995 where the ANC data showed a maximum higher HIV prevalence by 1.06 percent. On the contrary the VCT data yielded a higher prevalence by 1.4 percent during the period of 1996-2003. In the year 2010 however the projected HIV prevalence will be more by 2.2 percent if the VCT data were used. This irregularity in HIV prevalence using different data sources could be explained by variation in the inputs used for the EPP model that includes site prevalence value for the respective years and sample size difference in ANC and VCT clients entered.

Although variation in the prevalence value was noted between the two data sources, a similar trend in the progression of AIDS epidemic is observed using both the ANC and VCT data sources. This is consistent with a study conducted in Uganda in 2005 where the VCT based HIV prevalence was similar with the ANC modeled HIV prevalence implying that VCT data may provide a useful tool for monitoring the HIV epidemic in an urban settings where well established and expanded VCT services are available, (Baryarama et al., 2004).

Based on the two sets of data sources and the corresponding HIV prevalence obtained, the study shows that, in the absence of AIDS, the two major mortality indicators namely, infant mortality rate and under-5 mortality rate declines over the projection period. The presence of AIDS epidemic, however, slows down this decline, and in fact reverses it in some cases like expectation of life at birth. However, the crude death rate and the additional number of deaths resulting from HIV/AIDS have shown an increment over time with a reversing effect.

The fact that women are getting infected, falling ill and dying in the midst of their reproductive years means an increase in the number of babies born HIV-positive. The relative impact of AIDS on infant mortality will depend on the prevalence of HIV in the population, in addition to infant mortality from other causes. Approximately one-fourth to one-third of the children born to HIV-positive women is likely to acquire the infection from mothers. Pediatric HIV infection is expected to have a substantial impact on mortality during infancy and childhood.

In Addis Ababa infant mortality rate using ANC data in 1995-2000 is estimated at 82.6 deaths per 1,000 live births in the presence of AIDS, but only 71.9 per 1,000 live births in the absence of AIDS, that is, AIDS has already produced more than a 14.8 percent rise in infant mortality. By 2006-2010, infant mortality is expected to fall, to 62.3 per 1,000 live births, a level nearly 24.5 percent higher than what would have been attained in the absence of AIDS. The infant mortality rate using VCT data in 1995-2000 is estimated at 83.2 deaths per 1,000 live births. In the absence of AIDS we have 71.9 deaths per 1,000 live births. For 2006-2010 period, it is expected to be at least 22.1 percent higher than it would have been in the absence of AIDS. The findings in this study are in line with the findings documented by UNAIDS for 9 South and Eastern African countries where the infant mortality in 1995-2000 was estimated at 86 deaths per 1000 live births in the presence of AIDS but only 76 deaths per 1000 live births in the absence of AIDS. The impact of HIV on Infant mortality is also evidenced by studies conducted in Namibia, South Africa and Zimbabwe where infant mortality is expected to be at least 40 percent higher than it would have been in the absence of AIDS.

This study therefore, has demonstrated a very close estimate on the impact of Infant mortality rate using the ANC and VCT modeled HIV prevalence.

In a scenario without AIDS, it was estimated that under-5 mortality rate is expected to decline from 100.5 per 1000 live births in 1995-2000 to 69.0 per 1000 live births in the period 2006-2010. In contrast, as a consequence of AIDS, under-5 mortality rate declines from 116.3 to 85.3 per 1000 live births for the same period mentioned above using the ANC data. Except for the period 2006-2010 where there is a maximum of 1.9 percentage difference exists, this study revealed that, there is no significant difference among the U5MR estimates and projections constructed using ANC and VCT data sources. On average, under-5 mortality rate in the presence of AIDS during the period of 1995-2000 was 16.0 percent more than the figure obtained in the absence of AIDS. Further, U5MR could have been lower by 22.4 percent for the projected period of 2006-2010 in the absence of HIV/AIDS epidemic. Under-5 mortality rate is estimated to be more than double because of AIDS in Namibia, in Botswana 80 percent of deaths among children under-5 is due to AIDS where as 40 percent under-5 mortality in South Africa is due to AIDS. By 2015, AIDS mortality is estimated to make up nearly 80 percent of deaths in this age group in Botswana, two thirds of deaths in Namibia, and half of deaths in South Africa. Without the prevention of mother-to-child transmission therefore, under-5 mortality in the years to come will be significantly higher with AIDS than without AIDS in the study area. The findings in this study and that of the Southern African countries indicate that AIDS is increasing the number of child deaths, which would undoubtedly threaten to reverse many of the recent gains of child survival programs.

The most direct impact of HIV/AIDS is an increase in the number of deaths in the affected population. According to the results of this study, the additional number of deaths due to AIDS in Addis Ababa using ANC and VCT data will rise from 51,045 & 48,638 in 1995-2000 to 103,978 & 108,874 in 2001-2005 and to 139,248 & 139,415 in 2006-2010, respectively. Overall, between 1995 and 2010, the expected

additional cumulative deaths due to HIV/AIDS epidemic using ANC and VCT data sources are 294.3 thousand (45.0%) and 296.9 thousand (45.3%), respectively. A similar trend in the increase of the number of additional deaths due to AIDS epidemic was also noted in studies conducted on the demographic impact of HIV/AIDS in some selected countries. Both the ANC and VCT data sources indicate that, on average AIDS was the cause for about 32.7 percent of the total deaths during the period of 1995-2000 while it accounts for 48.9 percent of total deaths for the period 2006-2010. The study also revealed that, there is no as such significant difference in estimating and projecting the total number of deaths using ANC and VCT data sources.

In the absence of AIDS, the crude death rate for Addis Ababa is projected to decline from 8.9 deaths per 1,000 population in 1995-2000 to 7.6 deaths per 1,000 population in 2006-2010, whereas with AIDS using ANC data, the crude death rate, which starts at 13.4 deaths per 1,000 population in 1995-2000, is projected to reach 16.6 deaths per 1,000 population in 2001-2005 and then declines to 16.2 deaths per 1,000 population in 2006-2010. That is, in the period of 2006-2010, the crude death rate with AIDS is expected to be more than 114.1 percent higher than it would have been in the absence of AIDS. Because of the AIDS epidemic, the crude death rate using VCT data is estimated to be 13.2 deaths per 1,000 population in 1995-2000 and is projected to rise to 16.9 deaths per 1,000 population in 2001-2005 before falling to 16.3 deaths per 1,000 population in 2006-2010. The results indicate that between the years 2005 and 2010 alone AIDS is expected to at least be more than twice the crude death rate of Addis Ababa obtained in the absence of AIDS.

This finding is consistent with the data from Botswana, Kenya, Namibia, South Africa and Haiti where the crude death rates would have been in the single digit in the absence of AIDS but are in double digit with AIDS. In South Africa, for example, the

crude death rate in 2005 is estimated to be 21 per 1,000 population with AIDS versus 7 per 1,000 population without AIDS. In Botswana the crude death rate is estimated to be 29 per 1,000 population with AIDS versus 3.5 per 1,000 population without AIDS.

One of the most shocking indicators of the demographic effect of AIDS mortality is life expectancy at birth, a measure indicating the average number of years that a newborn child would live if mortality remained constant throughout his/her life time. This study also demonstrated that, life expectancy in Addis Ababa using ANC data is estimated at 50.8 years in 1995-2000 instead of the 59.7 years it would have been in the absence of AIDS, a loss of 8 years of life. By 2006-2010, the difference in life expectancy with and without AIDS is projected to reach 17 years. Similarly, life expectancy using VCT data is estimated at 51.1 years in 1995-2000 compared to 59.7 years in the absence of AIDS. It is projected to decrease to 46.3 years in 2001-2005 and 47.9 years in 2006-2010. In the absence of AIDS, it would have been expected to reach 64.6 years by 2006-2010, a difference of 17 years. Hence, both data sources indicate that, as a result of the increasing mortality due to AIDS, life expectancy has stagnated or declined in Addis Ababa and this trend is likely to continue through 2010.

Similarly, the estimated average life expectancy at birth in most African countries is 45 years which is on average 14 years of life less than it would have been without AIDS mortality. This is slightly lower than the result of this study but higher than countries like Namibia, Botswana and South Africa where they are estimated to have lost 24 to 42 years of life expectancy at birth as a result of AIDS mortality.

Partly because of the increase in mortality brought about by the HIV/AIDS epidemic, the rate of population growth has declined and will continue to do so in

urban areas that are affected by the epidemic. Similar to the results of the study on the impact of AIDS on annual population growth rates in 29 African countries, (UNAIDS & UN Population Division, 1998), the annual population growth rate for Addis Ababa using ANC data is also estimated at 2.95 percent per year in 1995-2000, the growth rate dropped to nearly 2.23 percent in the period 2001-2005 and is expected to decline to 2.12 percent per year in 2006-2010. Likewise, the Addis Ababa annual population growth rate using VCT data is also expected to decrease significantly, from 2.97 percent in 1995-2000 to 2.12 percent per year in 2006-2010, instead of remaining at a moderate 2.81 percent growth rate in the absence of AIDS.

This study therefore has demonstrated that, in Addis Ababa, the annual population growth will be significantly lower than it would have been in the absence of AIDS using both the ANC and VCT data sources. Contrary to Anderson et al. study which revealed that AIDS would bring about a negative population growth, (Anderson et al., 1991), the findings of this study using both data sources showed that AIDS would slow down the growth rate of the population of Addis Ababa, but would not lead to negative population growth in the coming years. This finding is in strong agreement with that of MOH study in Ethiopia, (MOH: *Technical Document*, 2004). It is believed that the difference of the findings is due to the difference in assumptions made on the future level of HIV prevalence.

As a direct consequence of lower population growth rate observed in this study, the population of Addis Ababa will be much smaller in the future than what would have been in the absence of HIV/AIDS epidemic in the capital city. That is, if there were no HIV/AIDS epidemic, the total population of Addis Ababa would increase from about 2,156,035 in the year 1995 to 3,444,345 in 2010. However, with a continued AIDS epidemic using ANC data, the total population of Addis Ababa would be

3,095,280 by 2010, which is 349,065 (10.1 %) less than the projection without AIDS. Likewise using VCT data the population of Addis Ababa in the presence of the pandemic is projected to be 3,093,580 which is 350,765 (10.2%) less than the projection in absence of AIDS epidemic. Similar reduction in the population size, as an effect of HIV/AIDS on the population size has been reported by studies conducted on the demographic impact of AIDS in 15 developing Countries (Laura et al., 2004). Although AIDS has a very serious relative effect on the population size in the long run, none of the results of this study shows a decline in population size, that leads to a negative population growth, for the entire projection period.

A maximum percentage difference of 0.15 percent in the total population size was observed in the year 2000 when ANC data is compared to the VCT data source. In this study, therefore, no significant difference was noted between the ANC and VCT data in determining the impact of HIV/AIDS on population size of Addis Ababa.

The impact of HIV/AIDS on the population growth rate of Addis Ababa is also reflected in the doubling time of affected population. This study also showed that, the population doubling time for Addis Ababa is significantly longer in the presence of AIDS as compared to the case considering the absence of the epidemic. That is, in the presence of the pandemic using ANC data, the population doubling time of Addis Ababa increases from 24.08 years in 1995-2000 to 33.02 in the period 2006-2010 which is 8 years longer in the absence of the epidemic for the same period. A similar pattern is also observed using the VCT data while projecting the population doubling time, implying that HIV/AIDS epidemic has prolonged or delayed the doubling time by about 8 years in 2010. This study therefore, has demonstrated no significant difference in determining the doubling time with the use of ANC and VCT data sources.

8. Study Limitation

- ↳ The investigator has analyzed data on VCT clients who might have visited the center more than one time that could have confounded the HIV prevalence determination for the respective years.

- ↳ There were also uncertainties noted while taking projected demographic parameters such as fertility (TFR), expectation of life at birth (male & female), migration, etc., for the period 1982-2010 (taken from the 1994 census reports for Addis Ababa) used as an input while projecting the population of Addis Ababa from 1982 to 2010.

- ↳ Due to lack of sufficient and reliable data on perinatal transmission rate, child and adult HIV incubation period, progression rate from AIDS to death for Addis Ababa in particular and the country at large, the investigator was forced to use rates documented elsewhere for Sub-Saharan African Countries. Thus, the findings in this study might have been affected by the scarcity of such region/country specific rates.

9. Conclusion

- ✚ A declining adult HIV prevalence was observed in an urban setting like Addis Ababa which is inconformity with the recent study conducted in Ethiopia by the Ministry of Health.
- ✚ This study suggests that VCT modeled HIV prevalence data closely approximate prevalence among all ANC attendees in Addis Ababa setting where there are very high participation rate exists to the routine VCT services.
- ✚ National HIV/AIDS estimate for Ethiopia is derived from modeling serial ANC based HIV prevalence data. In order to understand the dynamics of the epidemic and its determinants, additional data source such as VCT can be valuable to complement the ANC data in monitoring the HIV epidemic trend.
- ✚ Although ANC based surveillance provides a solid long-term data, the rapid expansion of routine VCT program can be considered as a potential to replace or supplement the ANC surveillance in an urban setting. However, special considerations need to be given for issues related to selection bias, data quality, accessibility and availability of individual records. The use of an alternative data source like VCT deem necessary in the Ethiopian context where a population based sero-prevalence survey is less likely to be conducted at a regular interval to monitor the HIV/AIDS epidemic trend.
- ✚ The impact of HIV AIDS on major demographic parameter has been evident in this study and found to be consistent with other similar studies undertaken in the developing countries, that calls for a concerted effort to curb the prevailing HIV/AIDS situation in the country in general and in the study area, Addis Ababa in particular where one of the highest HIV prevalence is reported.

- ✚ Based on the two sets of data sources and the corresponding HIV prevalence obtained, the study shows that, in the absence of AIDS, the two major mortality indicators namely, infant mortality rate and under-5 mortality rate declines over the projection period. The presence of AIDS epidemic, however, will slow down this decline, and in fact reverses it in some cases like crude death rate and expectation of life at birth.

- ✚ The scarcity of direct information about HIV prevalence among men has led researchers and policy makers to determine the magnitude using a proxy estimate that emanates from the female data sources. This study however has enabled the investigator to make an estimated and projected HIV prevalence for the men population in Addis Ababa using the available VCT data.

- ✚ Since the current study had revealed a lower HIV prevalence rate for males using the VCT data source, the national HIV estimate for Ethiopia that assumes an equal HIV prevalence as a baseline data for both sexes needs validation and further exploration to obtain a solid estimate from different source.

10. Recommendations

- ✓ Further research and development of analytic tools is necessary to improve the analysis of the different data sources including VCT, and to provide insight in the contribution of programs to desired changes in incidence and prevalence.
- ✓ Additional research on relation between ANC and VCT and continued monitoring of uptake of VCT services is therefore required to assess further the possible role of HIV prevalence data from VCT programs to monitor trends in the HIV/AIDS epidemic.
- ✓ A similar study is to be proposed to be undertaken using VCT data only for those who are not referred from other health centers and for new VCT clients visiting the center in order to enable researchers obtain a better HIV/AIDS estimate for Addis Ababa and thereby make a trend analysis and also evaluate the impact of the epidemic on population dynamics in the capital city.
- ✓ Estimates of the demographic impact of HIV/AIDS are dependent on the survival time from HIV infection to death. Even though the approximate median survival time for Sub-Saharan African Countries is 9 years for adults and 2 years for children, there is still a need to conduct further studies to validate these estimates in the Ethiopian context.
- ✓ Taking into account the significant impact of HIV/AIDS on the population dynamics, observed in this study, there is a need to incorporate the HIV/AIDS mortality and related impacts while undertaking population projections after undertaking a census in the country as well as in the study area, Addis Ababa.

- ✓ Trend analysis on epidemics like HIV/AIDS can raise many issues and potential biases that need to be taken into account when embarking on such kind of analysis. The most important questions that need to be addressed by analysis of HIV trends is whether the apparent trends in prevalence are real or the result of changing biases and selection effects, and whether it is possible to conclude that any change in incidence has occurred (to be differentiated from declining prevalence because of mortality overtaking incidence). Therefore, further exploration and studies using reliable data sources are recommended to know whether the decline in the estimated and projected adult HIV prevalence in Addis Ababa is a genuine or an artifact.

- ✓ A population based sero-prevalence survey, that would enable to achieve better HIV/AIDS estimates and serve as a benchmark for comparisons of estimates using data sources like ANC and VCT, need to be conducted and thereby to monitor the HIV/AIDS epidemic trend with high degree of accuracy in the rural and urban settings of the country.

- ✓ Despite current uncertainties, HIV/AIDS was clearly having a devastating effect on development in Ethiopia. Adult and child mortality due to AIDS had already increased dramatically in urban population, on occasion reversing over a short period the progress made in decades. There is no question that in a city like Addis Ababa with the highest HIV prevalence rate, the demographic impact of HIV/AIDS will be severe. National and international organizations need to improve their efforts to reverse the current HIV/AIDS trends, prevent millions of new infections in the coming years and, in the process, render current projections invalid.

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Annexes

Annex I: Glossary of Terms

Adult: an adult is defined as a person aged 15 or older.

Age-Specific Fertility Rate (ASFR): is defined as the number of births to women of a given age group per 1,000 women in that age group.

AIDS: is the abbreviation for the acquired immune deficiency syndrome, a disabling and fatal disease caused by the human immunodeficiency virus (HIV).

Annual Growth Rate (AGR): is the rate at which the population is increasing or decreasing in a given year due to natural increase and net migration, expressed as a percentage of the base population.

Coale-Demeny Model Life Tables: are families of life tables derived from empirical life tables of Europe and other industrialized nations of the world. They are based primarily on data from the first half of the 20th century.

Coale-Trussell Relational Fertility Model: this model incorporates (1) the timing of marriage, (2) a population's natural fertility, and (3) the degree of fertility regulation in a population. It permits users to generate a fertility schedule from an empirical baseline and a specific total fertility rate.

Cohort Component Projection: is a projection made by subjecting all cohorts, on an annual or five-year basis, to mortality and migration assumptions, and applying fertility assumptions to women of reproductive age.

Cohort: is a group of persons who experience certain events within a specified period of time, such as those who are born or who are married in the same year.

Crude Death Rate (CDR): is defined as the number of deaths in a year per 1,000 of the mid-year population.

Epidemiology: is the study of the incidence, distribution, and determinants of an infection, disease, or other health-related event in a population. Epidemiology can be thought of in terms of who, where, when, what, and why. That is, who has the infection/disease, where are they located geographically and in relation to each other, when is the infection/disease occurring, what is the cause, and why did it occur?

Expectation of Life at Birth: is the average number of years a newborn baby is expected to live if he/she is exposed throughout his/her life to the prevailing pattern of age specific death rates.

HIV-Infection: is infection with HIV. HIV infection is primarily a sexually transmitted infection, passed on through unprotected sex. The virus can also be transmitted through blood transfusions, through the use of un-sterilized injection equipment or cutting instruments, and from an infected woman to her fetus or nursing infant.

HIV Sentinel Surveillance: is the systematic collection and testing of blood from selected populations at specific sites, for example, pregnant women attending prenatal clinics for the purpose of identifying trends in HIV prevalence over time and place.

HIV: is the abbreviation for human immunodeficiency virus that causes AIDS. Two types of HIV are currently known: HIV-1 and HIV-2. Worldwide, the predominant virus is HIV-1. Both types of virus are transmitted by sexual contact, through blood, and from mother to child, and they appear to cause clinically indistinguishable AIDS. However, HIV-2 is less easily transmitted, and the period between initial infection and illness is longer in the case of HIV-2.

Incubation Period: is the time interval between infection and the onset of AIDS.

Infant Mortality Rate (IMR): is the number of deaths to infants (under one year of age) per 1,000 live births during the year.

Model Life Table: is a table of values based on a series of related functions having to do with survivorship over intervals of time.

Orphan: an orphan is defined as a child under the age of 15 whose mother has died of AIDS.

Perinatal and Perinatal Transmission: Pertaining to or occurring during the periods before, during, or shortly after the time of birth; that is, before delivery from the 28th week of gestation through to the first seven days after delivery. The transmission of HIV from an infected woman to her fetus or newborn child is referred to as perinatal transmission.

Population Doubling Time: is the number of years it would take for the population to double its current size at the current annual rate of growth.

Population Projection: Computations depicting the future course of a population's size, its structure, and its interaction with dynamics such as fertility, mortality, and migration. The projection is constructed based on assumptions about the future course of those population dynamics.

Prevalence: is the proportion of a defined population with the infection, disease, or other health-related event of interest at a given point or period of time.

Sero-prevalence (HIV, STD): is the percentage of a population from whom blood has been collected that is found, on the basis of serology, to be positive for HIV or other STD agents at any given time.

Total Fertility Rate (TFR): is the average number of children that would be born alive to a woman by the time she ended childbearing she were to pass through all her childbearing years conforming to the age-specific fertility rates of a given year. That is, the total number of children a woman would have if the fertility rates for a given year applied to her throughout her reproductive life.

Under-5 Mortality Rate (U5MR): is the number of deaths to children (under the age of five) per 1,000 live births during the year.

Annex II: Site Prevalence Values

Table II.1: HIV Prevalence (%) at the Five ANC Sentinel Sites in Addis Ababa

No	ANC Surveillance Site	Year								
		1989	1992-93	1995	1996	1997	1999-2000	2001	2002	2003
1	Akaki Health Center	-----	-----	-----	-----	-----	-----	-----	-----	10.9
2	Gulele Health Center	-----	-----	-----	-----	20.0	18.2	15.8	12.3	12.4
3	Higher 23 Health Center	-----	-----	-----	-----	14.1	10.7	12.3	10.2	11.8
4	Kazanchis Health Center	-----	-----	-----	-----	16.7	18.0	17.7	15.1	11.6
5	Teklehaymanot Health Center	-----	-----	-----	-----	18.5	14.0	16.6	15.1	15.1
<i>Total for Addis Ababa (Average)</i>		<i>4.6</i>	<i>11.2</i>	<i>21.2</i>	<i>17.8</i>	<i>17.3</i>	<i>15.2</i>	<i>15.6</i>	<i>13.2</i>	<i>12.4</i>

SOURCE: MOH, AIDS in Ethiopia: 5th Edition, June 2004.

Table II.2: Sub-City Level VCT Based Prevalence from 2003 to 2005 in Addis Ababa

Year	Sub-City	Tested			Positive			Prev.
		M	F	M+F	M	F	M+F	
2003	1 Addis Ketema	4836	5113	9949	566	1117	1683	16.92%
	2 Akaki Kality	5321	7875	13196	815	1375	2190	16.60%
	3 Arada	17435	32172	49607	1798	3263	5061	10.20%
	4 Gulele	942	1684	2626	199	527	726	27.65%
	5 Bole	4853	6293	11146	629	1248	1877	16.84%
	6 Kirkos	13528	21765	35293	1678	3484	5162	14.63%
	7 Nifas Silk Lafto	1237	2182	3419	188	549	737	21.56%
	8 Kolfe Keranyo	811	952	1763	127	163	290	16.45%
	9 Lideta	4281	4384	8665	519	986	1505	17.37%
	10 Yeka	1391	2659	4050	194	624	818	20.20%
Total		54,635	85,079	139,714	6,713	13,336	20,049	14.35%
2004	1 Addis Ketema	5006	4759	9765	709	913	1622	16.61%
	2 Akaki Kality	4612	6293	10905	628	906	1534	14.07%
	3 Arada	18606	25048	43654	1858	2604	4462	10.22%
	4 Gulele	3279	5459	8738	467	1182	1649	18.87%
	5 Bole	3000	3751	6751	413	547	960	14.22%
	6 Kirkos	25439	29222	54661	3177	4994	8171	14.95%
	7 Nifas Silk Lafto	3854	5082	8936	461	898	1359	15.21%
	8 Kolfe Keranyo	2208	2884	5092	226	423	649	12.75%
	9 Lideta	8279	10233	18512	969	1695	2664	14.39%
	10 Yeka	7082	9495	16577	851	1842	2693	16.25%
Total		81,365	102,226	183,591	9,759	16,004	25,763	14.03%
2005	1 Addis Ketema	6817	7611	14428	813	1394	2207	15.30%
	2 Akaki Kality	3015	3744	6759	373	588	961	14.22%
	3 Arada	12825	18257	31082	1352	2256	3608	11.61%
	4 Gulele	3319	5299	8618	371	909	1280	14.85%
	5 Bole	2279	3448	5727	293	486	779	13.60%
	6 Kirkos	18214	22914	41128	2287	3820	6107	14.85%
	7 Nifas Silk Lafto	6890	8719	15609	782	1440	2222	14.24%
	8 Kolfe Keranyo	1743	2727	4470	207	441	648	14.50%
	9 Lideta	6659	8376	15035	641	1248	1889	12.56%
	10 Yeka	6880	8607	15487	983	1294	2277	14.70%
Total		68,641	89,702	158,343	8,102	13,876	21,978	13.88%

Annex III: Projection and Inputs Used

Table III.1: Fertility (TFR), Mortality (Life Expectation) and Urbanization (%Urban) Inputs used for the projection, 1995-2010, Addis Ababa.

Period	1995-2000	2001-2005	2006-2010
TFR-Medium Variant	2.14	2.24	2.34
Male LE- Medium Variant	57.85	60.35	62.65
Female LE- Medium Variant	61.55	64.05	66.55
Percent Urban	100.00	100.00	100.00

Table III.2: Base Year (1995) Population and Back Projected (1982) Population of Addis Ababa by Sex and Age.

Base Year (1995) Population for the Projection				Back Projected (1982) Population			
Age Group	Sex		Total	$e^{rt} = e^{(-0.04*13)}$	Sex		Total
	Male	Female			Male	Female	
0-4	82363	73684	156047	0.56439552	46485	41587	88072
5-9	116053	126521	242574	0.56439552	65500	71408	136908
10-14	143926	170332	314258	0.56439552	81231	96135	177366
15-19	142713	169013	311726	0.56439552	80547	95390	175937
20-24	128007	143880	271887	0.56439552	72247	81205	153452
25-29	107240	117984	225224	0.56439552	60526	66590	127115
30-34	75739	83364	159103	0.56439552	42747	47050	89797
35-39	60606	61863	122469	0.56439552	34206	34915	69121
40-44	52888	42731	95619	0.56439552	29850	24117	53967
45-49	42106	31809	73915	0.56439552	23764	17953	41717
50-54	29380	24919	54299	0.56439552	16582	14064	30646
55-59	21598	19431	41029	0.56439552	12190	10967	23157
60-64	15422	15115	30537	0.56439552	8704	8531	17235
65-69	10853	11403	22256	0.56439552	6125	6436	12561
70-74	7134	8064	15198	0.56439552	4026	4551	8578
75-79	4206	5099	9305	0.56439552	2374	2878	5252
80 +	4893	7164	12057	0.56439552	2762	4043	6805
Total	1045127	1112376	2157503	Total	589865	627820	1217685

Table III.3: Assumptions and Inputs used in Spectrum Computer Program

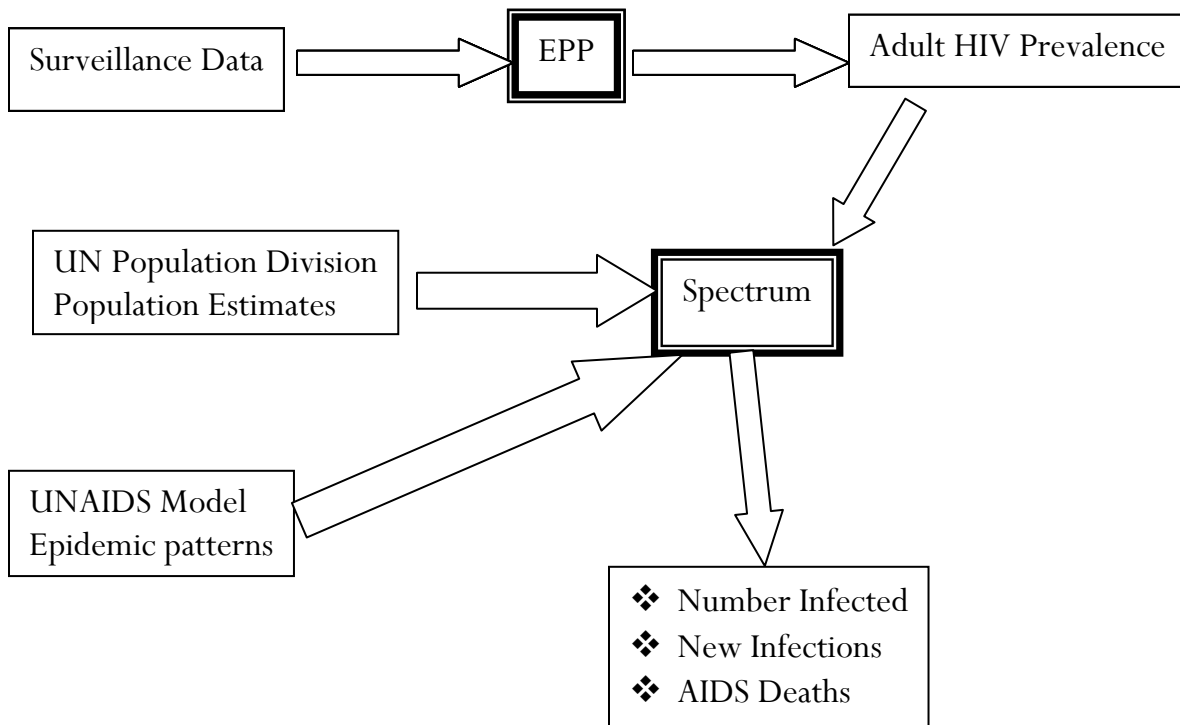
No	Spectrum Parameters	Assumptions and Inputs
1	Life Expectancy after HIV infection (median, adults)	9 years
2	Life Expectancy after HIV infection (median, children)	2 years
3	Life Expectancy after AIDS onset	1 year
4	Vertical HIV transmission risk	32%
5	Start of the epidemic in Addis Ababa	1982
6	Proportion of HIV-positive provided ART for PMTCT	0
7	Proportion of HIV-positive receiving ART	0
8	Probability to survive until following year with ART	80%
9	Fertility ratio HIV-pos/HIV-neg, 15-19 years	1.5
10	Fertility ratio HIV-pos/HIV-neg, 20-49 years	0.7
11	Sex ratio at birth (Male/Female)	1.03
12	Sex ratio of HIV prevalence, 1982	0.24
13	Sex ratio of HIV prevalence, 2003	1.3
14	Percent infants with AIDS dying in 1 st year	0.67
15	HIV age distribution by age and sex	SPECTRUM default table
16	HIV progression pattern, adults, pediatric	Fast
17	Age-Specific fertility pattern	UN Sub-Saharan Africa
18	Model life table	Coale-Demeny West

Annex IV: Methodologies and Assumptions in EPP and Spectrum Computer Packages

The UNAIDS/WHO approach to national HIV estimates requires the use of two special computer models: *EPP* and *Spectrum*. The estimates from these computer packages are based on surveillance data.

The EPP program fits a simple epidemiological model to find the best fitting curve that describes the evolution of adult HIV prevalence over time. The Spectrum program reads the prevalence projection produced by EPP and calculates the number of people infected, new infections, AIDS cases, AIDS deaths and others. These calculations are based on population estimates provided by the United Nations Population Division and model patterns prepared by the UNAIDS Reference Group that describe the progression from infection to death, the distribution of infection by age and sex, transmission from mother-to-child and the effect of HIV infection on fertility, (UNAIDS/WHO, 2003).

Figure IV.1: Input-Output Relationships of EPP and Spectrum Computer Programs

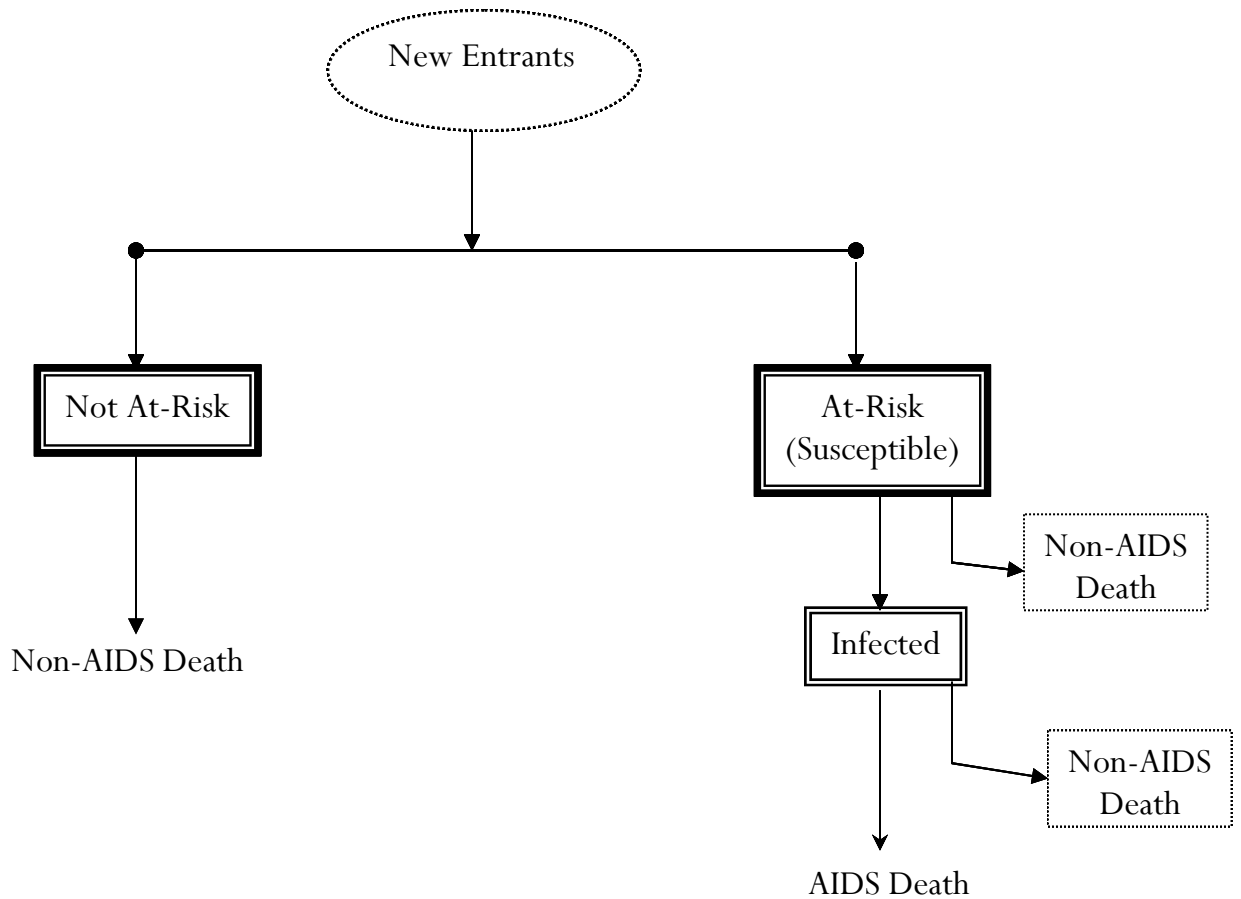


Annex IV.1: Methodology in Estimating & Projecting HIV Prevalence Using EPP Computer Software

The methodology for estimating prevalence from surveillance data was developed by the UNAIDS Reference Group on Estimates, Models and Projections. The software which is known as Estimation and Projection Package (EPP) is applied in order to produce estimate on adult HIV/AIDS prevalence of a given country. EPP is a simple epidemiological model that produces the basic epidemic curve shapes found in most HIV epidemics, (UNAIDS/WHO, 2003).

The EPP model structure is shown below:

Figure IV.2: EPP Software Model Structure



The population is initially divided into two parts, those who are NOT AT RISK of HIV infection and those who are AT RISK. People would not be AT RISK if they are not sexually active, if they have only one partner who has no outside partners, or if they successfully use condoms all the time. New entrants are children reaching the age of 15. They can enter either of the population group. Some of those who are AT RISK will become infected and progress to AIDS death. All population groups are subject to this risk of dying from causes other than AIDS. The dynamics of this model are described by four parameters:

- **t_0 :** The initial (start) year of the HIV/AIDS epidemic. An earlier start year will cause the curve to rise earlier and a later start year will produce a curve that starts later.
- **f_0 :** The initial proportion of the population that is in the AT RISK category. This parameter determines the peak of the epidemic curve.
- **r :** The force of infection. This governs the rate at which people in the susceptible population become infected. A large value of r will cause prevalence to increase rapidly while a small value will cause it to increase slowly.
- **Φ (Phi):** A parameter that affects the distribution of new entrants to the NOT AT RISK and AT RISK categories. This parameter determines the degree to which susceptible people who die from AIDS are replaced by people who previously were NOT AT RISK. The value of Φ determines the amount of decline in prevalence after it reaches a peak. A large value of Φ will produce a small prevalence decline, while a small value of Φ will produce a large prevalence decline.

The model is described as follows:

$$\begin{aligned}
 Z &= \text{AT RISK population,} & Y &= \text{infected Population} \\
 X &= \text{NOT AT RISK population,} & \text{and} & N = X + Y + Z
 \end{aligned}$$

The population not at risk (**X**) is increased by new entrants and reduced by non-AIDS

deaths (μX):
$$\frac{dX}{dt} = [1 - f(X/N)] \cdot E_t - \mu X$$

The population at risk (**Z**) is increased by new entrants and reduced by non-AIDS

deaths and new HIV infections (rY/N):
$$\frac{dZ}{dt} = f(X/N) \cdot E_t - (\mu + rY/N + I) \cdot Z$$

The infected population (**Y**) is increased by new infections (rY/N and **I**) and decreased by progression to AIDS death:

$$\frac{dY}{dt} = (rY/N + I) \cdot Z - \int_0^t (rY_x / N_x + I_x) \cdot Z_x \cdot g(t-x) dx$$

Where:

μ = the Non-AIDS death rate

$\ell=1$ for the first year of the epidemic and **0** for all other years.

g = function describing the proportion progressing to AIDS death by the number of years since HIV infection.

The fraction of those individuals entering the adult population (E_t) who enter the at-risk group (**Z**) $f(X/N)$ is given by:

$$f(X/N) = \frac{\exp\left[\phi\left(\frac{X}{N} - (1 - f_o)\right)\right]}{\exp\left[\phi\left(\frac{X}{N} - (1 - f_o)\right)\right] + \frac{1}{f_o} - 1}$$

This function determines the proportion of new entrants to the adult population that enter the at-risk population. Initially this proportion is set by f_o . As the epidemic progresses those in the at-risk category become infected with HIV and die. Since the death rate will be higher in the at-risk category than among those not at risk, the proportion of the population at risk will gradually decline. This will produce a prevalence curve that rises to a peak value and then declines rapidly to low levels. In many epidemics, however, prevalence stabilizes at or near its peak value. This can be

simulated by directing more entrants to the at risk category as the proportion of the population in the at-risk category declines. The parameter f_o determines the size of this effect. At high values of f_o new entrants will join the at-risk category in large enough numbers so that the proportion of the total population in the at-risk category remains nearly constant. When f is zero, the proportion of entrants going to the at-risk category does not change from its initial value. Negative values of f_o cause the proportion of entrants to the at-risk category to drop as AIDS deaths increase. These equations can produce a prevalence curve that can fit a wide variety of epidemic shapes by adjusting the four parameters: t_o , f_o , r , and Φ .

EPP uses this model to find prevalence curves that fit available surveillance data. The parameter μ (the non-AIDS death rate) is estimated for each country from the population estimates and projections of the United Nations Population Division. The progression to AIDS death (g) is assumed to be constant throughout the projection. It is a Weibull function that has been fitted to available information on survival times. The progression pattern used in EPP is discussed below.

New entrants to the adult population at time t , E_t are calculated from the births of HIV-negative children B_{t-15} occurring 15 years previously and the probability of surviving to age 15, l . The number of births is simply the birth rate multiplied by the size of the adult population. However, some children will be born infected. We assume that they do not survive to age 15. Thus the number of children born without HIV infection is determined by calculating births to HIV-negative adults [$b(X+Z)$] and HIV-negative births to HIV-positive adults [$b'Y(1-v)$] where v is the perinatal transmission rate and b is the birth rate adjusted for the reduction in fertility caused by HIV infection, ϵ .

$$E_t = B_{t-15} \cdot l, \quad B_{t-15} = b \cdot [X_{t-15} + Z_{t-15} + (1-v) \cdot \epsilon \cdot Y_{t-15}]$$

This approach is implemented in the EPP model by assuming that the parameters l (survival to age 15), b (birth rate), ε (fertility reduction caused by HIV), v (perinatal transmission rate) and the distribution g (progression from infection to AIDS death) are fixed. The initial values of the population size, survival to age 15 and the birth rate are derived from the population estimates of the United Nations Population Division.

Generally, EPP searches for the best values of the four remaining parameters t_0 (start year), f_0 (fraction at-risk), r (force of infection) and Φ (adjustment for AIDS deaths). The best values are defined as those that produce the prevalence curve that best fits the surveillance data. The best fit is determined by minimizing the sum of the squared errors (the differences between the model curve and the surveillance estimates in each year).

Annex IV.2: Methodology of Spectrum Computer Program

Spectrum is used to determine the consequences of the HIV/AIDS epidemic, including the number of people living with HIV/AIDS by age and sex, the number of AIDS deaths, and the number of orphans as a result of AIDS, as well as other demographic indicators of interest, such as life expectancy and mortality rate before age 5.

The core of Spectrum is a demographic projection model, called DemProj, that projects the population by age and sex. Other modules interact with the demographic projection. The HIV/AIDS projections are added to the demographic projections using a module called AIDS Impact Model (AIM). These modules address a variety of issues including impacts of HIV/AIDS (AIDS Impact Model; AIM), resource allocation for HIV/AIDS programs (Goals), the cost effectiveness of programs to PMTCT of HIV, options in family planning programs (FamPlan), adolescent reproductive health (NewGen), and the consequences of high fertility and rapid population growth (RAPID). Spectrum contains a database of population information that provides instant access to the population estimates and projections of the United Nations Population Division for all countries and regions of the world, (Stover J., 2005).

IV.2.1. Demographic Projections

The demographic projection component of Spectrum, *DemProj*, is a full featured cohort component projection model. The inputs are the population by age and sex in the base year, the total fertility rate over time, the age distribution of fertility, life expectancy at birth in the absence of AIDS, the age pattern of mortality, and the number and distribution by age and sex of migrants. The projection can start in any year from 1950 to 2005 and extend as far as 2050. The distribution of fertility and

mortality by age can be set by selecting from a list of model life tables. DemProj calculations are based on the standard cohort component projection modified to produce a single-year projection, (Stover, J and Sharon K., 2004).

A. Calculating the Base Population by Single Ages

The first step is to separate the population by five-year age groups into single years of age. This is achieved through the use of the Beers formulas, (Beers, 1945).

❖ **The 0-4 age group is split using the following formulas:**

$$a_0 = 0.3333 \cdot p_1 - 0.1636 \cdot p_2 - 0.0210 \cdot p_3 + 0.0796 \cdot p_4 - 0.0283 \cdot p_5$$

$$a_1 = 0.2595 \cdot p_1 - 0.0780 \cdot p_2 + 0.0130 \cdot p_3 + 0.0100 \cdot p_4 - 0.0045 \cdot p_5$$

$$a_2 = 0.1924 \cdot p_1 + 0.0064 \cdot p_2 + 0.0184 \cdot p_3 - 0.0256 \cdot p_4 + 0.0084 \cdot p_5$$

$$a_3 = 0.1329 \cdot p_1 + 0.0844 \cdot p_2 + 0.0054 \cdot p_3 - 0.0356 \cdot p_4 + 0.0129 \cdot p_5$$

$$a_4 = 0.0819 \cdot p_1 + 0.1508 \cdot p_2 - 0.0158 \cdot p_3 - 0.0284 \cdot p_4 + 0.0115 \cdot p_5$$

where p_1, p_2, p_3, p_4 and p_5 are the population aged 0-4, 5-9, 10-14, 15-19 and 20-24 respectively and a_0, a_1, a_2, a_3 and a_4 are the populations at single ages 0, 1, 2, 3 and 4 respectively.

❖ **Similarly, the 5-9 age group is split using the following formulas:**

$$a_5 = 0.0404 \cdot p_1 + 0.2000 \cdot p_2 - 0.0344 \cdot p_3 - 0.0128 \cdot p_4 + 0.0068 \cdot p_5$$

$$a_6 = 0.0093 \cdot p_1 + 0.2268 \cdot p_2 - 0.0402 \cdot p_3 + 0.0028 \cdot p_4 + 0.0013 \cdot p_5$$

$$a_7 = -0.0108 \cdot p_1 + 0.2272 \cdot p_2 - 0.0248 \cdot p_3 + 0.0112 \cdot p_4 - 0.0028 \cdot p_5$$

$$a_8 = -0.0198 \cdot p_1 + 0.1992 \cdot p_2 + 0.0172 \cdot p_3 + 0.0072 \cdot p_4 - 0.0038 \cdot p_5$$

$$a_9 = -0.0191 \cdot p_1 + 0.1468 \cdot p_2 + 0.0822 \cdot p_3 - 0.0084 \cdot p_4 - 0.0015 \cdot p_5$$

The age groups from 10-14 to 70-74 are split using the following formulas:

$$a_1 = -0.0117 \cdot p_{a-2} + 0.0804 \cdot p_{a-1} + 0.1570 \cdot p_a - 0.0284 \cdot p_{a+1} + 0.0027 \cdot p_{a+2}$$

$$a_2 = -0.0020 \cdot p_{a-2} + 0.0160 \cdot p_{a-1} + 0.2200 \cdot p_a - 0.0400 \cdot p_{a+1} + 0.0060 \cdot p_{a+2}$$

$$a_3 = 0.0050 \cdot p_{a-2} - 0.0280 \cdot p_{a-1} + 0.2460 \cdot p_a - 0.0280 \cdot p_{a+1} + 0.0050 \cdot p_{a+2}$$

$$a_4 = 0.0060 \cdot p_{a-2} - 0.0400 \cdot p_{a-1} + 0.2200 \cdot p_a + 0.0160 \cdot p_{a+1} - 0.0020 \cdot p_{a+2}$$

$$a_5 = 0.0027 \cdot p_{a-2} - 0.0284 \cdot p_{a-1} + 0.1570 \cdot p_a + 0.0804 \cdot p_{a+1} - 0.0117 \cdot p_{a+2}$$

where a_1, a_2, a_3, a_4 and a_5 are the first, second, third, fourth and fifth ages in the particular age group and p_{a-2} is the population of the age group two groups younger than the reference group, p_{a-1} is the population of the age group one group younger than the reference group, and so on.

❖ **The 75-79 age group is split with the formulas:**

$$\begin{aligned}
 a_{75} &= -0.0015 \cdot p_{60-64} - 0.0084 \cdot p_{65-69} + 0.0822 \cdot p_{65-69} + 0.1468 \cdot p_{65-69} - 0.0191 \cdot p_{80+} \\
 a_{76} &= -0.0038 \cdot p_{60-64} + 0.0072 \cdot p_{65-69} + 0.0172 \cdot p_{65-69} + 0.1992 \cdot p_{65-69} - 0.0198 \cdot p_{80+} \\
 a_{77} &= -0.0028 \cdot p_{60-64} + 0.0112 \cdot p_{65-69} - 0.0248 \cdot p_{65-69} + 0.2272 \cdot p_{65-69} - 0.0108 \cdot p_{80+} \\
 a_{78} &= 0.0013 \cdot p_{60-64} + 0.0028 \cdot p_{65-69} - 0.0402 \cdot p_{65-69} + 0.2268 \cdot p_{65-69} + 0.0093 \cdot p_{80+} \\
 a_{79} &= 0.0068 \cdot p_{60-64} - 0.0128 \cdot p_{65-69} - 0.0344 \cdot p_{65-69} + 0.2000 \cdot p_{65-69} + 0.0404 \cdot p_{80+}
 \end{aligned}$$

❖ **Ages 80 and above are aggregated, and by definition are not split into single years.**

B. Survival Ratios

Survival ratios are the proportion of the population of a particular age that survives to the next age in the next year. The life tables used in DemProj provide single-year survival ratios from birth to age one, age one to two, two to three, three to four, and four to five. Beyond age five the tables provide five-year survival ratios (the proportion of a five-year age group that survives to the next five-year age group five years later). These five-year survival ratios are converted to single-year survival ratios by taking the fifth root of the five 74 year survival ratio. The result is used as the survival ratio for all five ages in the corresponding age group.

C. Migration

The net number of migrants during a particular year for each age and sex group is determined as the total number of migrants for that sex in the previous year, multiplied by the proportion that are in the corresponding five-year age group, divided by five. (The distribution of migrants is entered for five-year age groups. These are divided by five to estimate the number of migrants at each single age within the five-year age group.)

D. Deaths

The number of deaths occurring during the year to persons of a particular age and sex at the beginning of the year are calculated as follows:

$$\boxed{\text{deaths}_{a,s,t-1,t} = (\text{pop}_{a-1,s,t-1} + \text{mig}_{ra-1,s,t-1} / 2) * (1 - S_{r,a,s,t})}$$

where:

$deaths_{a,s,t-1,t}$ = deaths occurring as people age from age group a-1 at time t-1 to age a at time t

$pop_{a,s,t}$ = the population of age group a and at time t

$migr_{a-1,s,t-1}$ = the net number of migrants of age group a-1 at time t-1

$Sr_{a,s,t}$ = the survival ratio, or proportion of the population of age group a-1 and sex s at time t-1 that survives to age group a at time t.

E. Population Size

The population of most age groups is calculated as the number of people one year younger one year ago, plus the net migration during the year, minus the number of deaths:

$$pop_{a,s,t} = pop_{a-1,s,t-1} + migr_{a-1,s,t-1} - deaths_{a,s,t-1,t}$$

For the last age group, the population also includes those who were in the last age group one year ago and survive to the present year:

$$pop_{80+,s,t} = pop_{79,s,t-1} + migr_{79,s,t-1} - deaths_{79,s,t-1,t} + pop_{80+,s,t-1} + migr_{80+,s,t-1} - deaths_{80+,s,t-1,t}$$

The population under one year of age is calculated as the number of births during the year that survive to the end of the year plus the net migrants:

$$pop_{0,s,t} = births_{s,t} + migr_{0,s,t-1} - deaths_{0,s,t-1,t}$$

F. Births

The number of births in a year is calculated from the number of women of reproductive age, the TFR and the age distribution of fertility.

$$births_{a,t} = TFR_t \cdot ASFP_{a,t} \cdot pop_{a,female,t}$$

where:

$births_{a,t}$ = the number of births to women at age a

TFR_t = the total fertility rate at time t

$ASFP_{a,t}$ = the proportion of lifetime fertility that takes place at age a.

$$Births_t = \sum_a births_{a,t}$$

Births by sex are calculated from total births and the proportion of births of that sex. The proportion of male births is equal to the sex ratio at birth divided by the ratio plus 100.

The proportion of female births is one minus the proportion of male births.

$$\text{births}_{s,t} = \text{births}_t * \text{PBS}_s$$

$$\text{PBS}_{\text{male}} = \text{Sex Ratio at Birth} / (\text{Sex Ratio at Birth} + 100)$$

$$\text{PBS}_{\text{female}} = 1 - \text{PBS}_{\text{male}}$$

IV.2.2. HIV/AIDS Projection Methodology

The HIV/AIDS projections are added to the demographic projections using a module called *AIM*. This module uses the projection of adult HIV prevalence prepared using the EPP model. It also requires assumptions about the epidemiology of HIV including the ratio of female to male prevalence, the distribution of infection by age, the distribution of the time from infection until AIDS death, and the effect of HIV on fertility, (Stover J., Feb. 2005). A simplified version of the methodology in HIV/AIDS calculations by age and sex is described below:

The number of adults of age (**a**) and sex (**s**) infected with HIV in any year **t** is simply the number of adults multiplied by the HIV prevalence:

$$\text{HIV}_{a,s,t} = (\text{Adult-Population}_{a,s,t}) * (\text{Prevalence}_{a,s,t})$$

The number of new infections each year is calculated as the number required to achieve the specified prevalence. Thus, new infections are calculated as the total number of infections expected in year **t** minus the number of infections surviving from the previous year. Surviving infections are the number of infections in the previous year minus deaths from AIDS or other causes occurring during the previous

year:
$$\text{New HIV infections}_{a,s,t} = \text{HIV}_{a,s,t} - [\text{HIV}_{a-1,s,t-1} - \text{AIDS deaths}_{a-1,s,t-1} - \text{Non-AIDS deaths to HIV}^+_{a-1,s,t-1}]$$

AIDS deaths are a function of the number of new infections in previous years and the rate of progression from infection to death:

$$\text{AIDS deaths}_{a,t-1} = \sum_{i=0}^{20} (\text{New HIV infections}_{a-i,t-i}) * (\text{Proportion that die from AIDS } i \text{ years after infection})$$

We assume HIV infected people are subject to the same hazard of mortality from causes other than AIDS as are people who are not infected.

Child infections occur when an HIV positive mother passes the infection to her child during gestation or birth or after birth through breastfeeding:

$$\text{New child infections}_t = (\text{HIVWRA}_t) * (\text{TFR}_t) * (1 - \text{TFRreduction}) * (\text{PTR}_t)$$

Where: **HIVWRA** is the number of HIV positive women of reproductive age; **TFR** is total fertility rate; **TFRreduction** is the reduction in fertility caused by HIV infection; and **PTR** is the perinatal transmission rate.

Children progress from infection to AIDS and death in the same manner as described above for adults, although the progression rates are different.

Declaration

This thesis is my original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged.

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