Considerations and Recommendations in Undertaking Population Projections for South Africa Intended to Assess the Impact and Consequences of HIV / AIDS
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CONSIDERATIONS AND RECOMMENDATIONS IN UNDERTAKING POPULATION PROJECTIONS FOR SOUTH AFRICA INTENDED TO ASSESS THE IMPACT AND CONSEQUENCES OF HIV/AIDS

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The research upon which this paper is based was supported by Human Sciences Research Council, the South Africa Department of Social Development, a Mellon Foundation grant to the Population Studies Center, University of Michigan, and a National Institutes of Child Health and Human Development Infrastructure grant HD41028 to the Population Studies Center, University of Michigan.

Helpful comments were provided by Oumar Bouare, Pieter Kok, Heston Phillips, John Romani, and Hillary Southall.

Views presented in this paper are those of the authors and do not represent positions of the University of Michigan, the Human Sciences Research Council, or the South Africa Department of Social Development.
Abstract

This paper discusses the use of population projections for South Africa in estimating the future demographic impact of HIV/AIDS. These issues raised apply to projections generally and to projections of the impact of HIV/AIDS in other countries. A focus of this paper is examination of the assumptions underlying projections and assessment of the robustness of the projections to violations of these assumptions.

It is prudent to set ranges of assumptions for a wide variety of factors that influence the results of a population projection. It would be an unmanageable task to do projections that used all possible combinations of assumptions. It is suggested that for each factor considered, preliminary analysis be undertaken to determine whether the reasonable range of assumptions for that factor is likely to make a substantial difference in the outcome of a projection, when other factors are held constant. If variations in a given factor make little difference, then the work can proceed with a single value assumed for that factor. Thus, preliminary analysis is actually a sensitivity analysis that should lead to final projections being carried out under a manageable number of combinations of assumptions.

Recommendations for these projections are:

1. Cohort-component projections should be done for the two sexes separately.

2. The age-specific fertility and mortality schedules applied for each five-year period should be explicitly stated.

3. The fertility and mortality schedules used to project a normal future should result from a serious consideration of the likely possible future variation in these schedules.

4. The effects of AIDS on fertility and mortality schedules used in the projections should result from serious consideration of the likely future effects of AIDS on these schedules. It needs to be decided whether to take interactions between non-AIDS morbidity and HIV-positive status into account in estimating mortality schedules.

5. All assumptions in the projections should be clearly stated.

6. There needs to be a decision whether projections that take HIV/AIDS into account concerning the size and composition of the estimated active AIDS population are stable enough to influence policy planning.

7. The projections produced should encompass a range rather than a single projection without AIDS and a single projection with AIDS.

8. The projections should be done separately for the African and non-African populations and then combined at the end to assess the overall result.

9. It must be decided whether and how to incorporate international migration.

10. The size, age-sex, and ethnic composition of the base population need to be decided.

11. Preliminary analysis can reveal whether employing a range in a given assumption makes a substantial or a trivial difference in a projection. If it makes a trivial difference, then a single value can be used for that assumption in further projections. Thus, the final number of projections presented would be less than the maximum number possible.
CONSIDERATIONS AND RECOMMENDATIONS IN UNDERTAKING POPULATION PROJECTIONS FOR SOUTH AFRICA INTENDED TO ASSESS THE IMPACT AND CONSEQUENCES OF HIV/AIDS

The future population of South Africa and how it will be affected by HIV/AIDS has policy and scientific significance. There have been many projections of South Africa’s population, several of which have estimated the impact of HIV/AIDS. Some projections have been part of research on numerous countries (Population Reference Bureau, 1998; United Nations, Population Division, 2001; United States, Bureau of the Census, 1999), while others have been done with South Africa specifically in mind (Calitz, 1991, 1996; Dorrington, 1998; Dorrington et al, 2001; Doyle & Millar, 1990; Johnson & Campbell, 1982; Jordaan et al, 1991; Martins, 1996; Mostert & van Tonder, 1987; Sadie, 1988, 1993; Simkins, 1983; South Africa, Department of Statistics, 1976; South Africa, Science Committee of the President’s Council, 1983; Steenkamp, 1989; Udjo, 1997, 1999; van Aardt et al., 1999).

These projections of South Africa’s population have been criticised from many perspectives. There have been several reviews of models of HIV/AIDS that look at the relevance of these models for population projections (Bah, 2000; Karon et al., 1998; Palloni, 1996; Palloni & Glicklich, 1991).

One limitation of many population projections for South Africa is that only a single projection has been produced. This gives an implied predictive certainty to the projection that is not warranted.

This paper discusses the many different purposes of projections and points out some considerations that should be borne in mind when projections of South Africa’s population are done for the purpose of assessing the impact of HIV/AIDS. Attention to these issues should improve the quality of future projections and should make clear to the potential users or critics the bases upon which those projections were made.

THE NATURE OF A POPULATION PROJECTION

In a projection, the size of the future population of a country or of a subnational unit, such as a region or ethnic group, is estimated. Although there are crude estimation methods, such as inflating the total population at one date by an assumed overall annual growth rate, most serious projections use the cohort-component approach (Preston et al., 2001: 119-121). In the cohort-component approach, the population at the start date is disaggregated by sex and age. Sometimes the population is divided into single years of age, but usually it is presented by five-year age group, with the 0-4 age group further divided into those age 0 (less than one year of age) and those age 1-4. There is also an open age interval for all those older than a given age.

This initial population is projected forward through the application of age-specific fertility and mortality schedules. If the population is to be projected by five-year age group, then the fertility schedules are specific for women in every five-year age group 15-49. There are separate mortality schedules for males and females. The mortality schedules for each sex are applied to each age group. Sometimes net migration schedules by age or in-migration and out-migration schedules by age are also included.

The result is the population estimated by sex and by age at some particular date. From this projected population, a number of useful things can be calculated, including the number of people over age 60,
the number of school-age children, the number of people in the working ages, and the ratio of those over retirement age to those in the working ages.

Different age-specific fertility, mortality, or migration schedules can be applied to the same starting population to produce another projection. A comparison of projections reveals the effects on the population of the difference between the schedules used in the two projections (Cliquet et al., 1993).

If sub-populations, such as different ethnic and racial groups, are known to have had very different fertility, mortality, or migration experience in the past and/or if these subpopulations are thought likely to have very different fertility, mortality, or migration experience in the future, the entire projection can be done separately for the given subpopulations. To obtain the total projected population of the country as a whole, the various projected subpopulations are added together.

**PURPOSES OF POPULATION PROJECTIONS**

Population projections are done for a variety of reasons:

1. **Projection as a Prediction or Forecast.** The purpose of a projection that most people think of first is a prediction or forecast of the actual future size and age-sex composition of a population. This has been the main purpose of many projections of the population of South Africa (c.f., Sadie, 1973, 1993; Udjo, 1999; van Aardt et al., 1999). Sometimes the main purpose is a projection for a particular region (Grobbelaar, 1985; van Zyl, 1983).

Governments assess the success of these projections by comparing the projected population by age and sex to a given date with the actual population at that date (Long, 1992; Smith & Bayya, 1992). By this standard, population forecasts have been at best moderately successful.

Mostert (1982) examined the assumptions behind and compared the results of projections of South African population groups done before 1980 to enumerations of the population groups in 1980. He found that all of the earlier projections had been overestimates, due to greater than anticipated fertility decline within each of the four population groups and due to less than anticipated immigration by Whites.

In 1935, the Scripps Institute forecast the 1970 population of the United States to be 155 million, while the actual 1970 U. S. population was 203 million. The forecast population size was 76% of the actual population size (Keyfitz, 1977: 231).

Sometimes the entire thrust of the forecast is incorrect either for a country or for an entire set of countries. In 1943, the well-known American demographers Warren Thompson and P. K. Whelpton forecast that the population of the United States would begin to decline after peaking in 1985 (Davis, 1948: 608), a conclusion that was obviously incorrect. Regarding the developed countries as a whole, Spengler wrote in 1938:

> “Within the next quarter century true depopulation – a persistent long-run excess of deaths over births – will manifest itself in nearly all the countries of Europe and in those non-European countries to which Western civilization has spread (Spengler, 1938: 3).”

By 1965-69, a quarter of a century after the above was written, the more-developed regions of the world as a whole had an annual rate of natural increase of 8 per 1000 population (United Nations, Population Division, 1999: 3).
A forecast is the result of a guess about the future course of fertility, mortality, and migration. If this guess is wrong, the forecast population will not match the actual population at the future date. A forecast in which a single predicted population is produced is very suspect because the single result implies a precision that is usually unwarranted.

Sometimes this problem of the excessive certainly implied by a single projected future population is addressed by producing statistical confidence intervals around the forecast (Lutz, 1996; Lutz et al., 2000; Keyfitz, 1977: 236). These confidence intervals are the result of using a distribution for each assumption, based on a solicitation of expert opinion on the likely future distribution for that input. The confidence interval approach reduces the problem of excessive implied precision. However, the certainty of the calculation of these confidence intervals has been questioned (Lee, 1998), since the confidence intervals themselves are based on assumptions.

A forecast is turned around when the fertility and mortality schedules in effect for a time period in the past are not known with certainty. Then projections can determine what those fertility and mortality schedules could have been. For example, Simkins (1999b) and Udjo (1999) each took the South African Census counts from 1970 and from 1996 and tried to determine what the age-specific fertility and mortality rates had been in the twenty-five year period between 1970 and 1995.

2) Projections to Produce Forecasts Under Alternative Likely Futures. Another purpose of a projection is to forecast the population when there is acknowledged to be uncertainty about the future, but when one of a small number of alternative futures is extremely likely. Sadie (1988) and Mostert & van Tonder (1987) projected the South African population under alternative fertility assumptions. Van Tonder & Mostert (1980) projected the population of South Africa by population group under two different fertility assumptions. Simkins (1983) projected the African population of South Africa under alternative likely future patterns. Government projections for states of the United States were done under four different internal migration assumptions because the pattern of future internal migration was uncertain (Wetrogan, 1990).

When the United Nations does projections of the future population of countries of the world, although the result is a population forecast, three different projections are typically presented, according to a low, a medium, and a high fertility assumption. This is done because the future course of fertility in a country is especially uncertain and has a large effect on subsequent population size.

Policy decisions informed by forecasts can change what subsequently happens to populations. One of the motivations for the intensive family planning programs that began in the 1960s in many countries was the implied demands on the economy and society that would be generated by the large populations predicted in the United Nations population forecasts.

3) Projections to Determine the Implications of a Proposed Policy. Sometimes the purpose of a projection is to see the implications of a proposed policy. In this case, the projection is not a forecast or prediction of what the population actually will be in the future. Rather this kind of projection says, “If the following policy is implemented and if the resulting fertility, mortality, and migration schedules were in effect, then this would be the result.”

The aim can be to see what the consequences would be of a policy that actually has been implemented or will be implemented or the purpose can be to determine whether a policy is feasible or would have undesirable implications. For example, van Rensburg (1975) determined what assumptions would be necessary in population projections in order for South Africa to reach zero population growth.
Mostert, Kok et al. (1985) estimated the effects on the size and location of the African population of South Africa under four alternative scenarios. The scenarios to different degrees abolished the influx controls that were implemented as a part of the system of apartheid to limit rural-urban migration by Africans. The scenarios also posited different development paths in what were then the African homelands.

Many European countries have looked to immigration as a way to maintain the size of their working-age population and to maintain a fairly high ratio of those in the working ages to the elderly, in order to support pay-as-you-go retirement schemes. Using projections, the United Nations Population Division (2000) showed the large, and in some ways undesirable, impact on the population that implementation of these policies would have.

When China proposed its fertility limitation program in the 1970s, some demographers advised against its implementation with the rapidity planned, because projections had shown that the fertility reduction would lead to a rapid increase in the proportion of China’s population that was elderly, along with a deficit of adult children to support them (Coale, 1981). This is what happened.

(4) Projections to Determine the Implications of a Pattern of Population Growth for a Given Phenomenon. As in purpose (3), this kind of projection also is not a prediction or forecast. This kind of projection says,

“If there is a given pattern of population growth, then this is the implication for the school-age population, the labor force, or whatever other phenomenon is of interest.”

Sometimes the aim of a projection is to see the effects of projected population growth on some other phenomenon. Mostert & van Tonder (1982) projected the population of South Africa by population group under three fertility scenarios because they were not sure what would actually occur in the future and because they thought the results of the projections of the alternative possible futures were relevant to policy development in South Africa. The findings of this study were one reason that a Population Development Programme within the South Africa Department of National Health was established in 1984 (Mostert, Hofmeyr et al., 1998: 227).

Heilig & Krebs (1987) projected the population of sub-Saharan Africa under various scenarios, including attainment of zero population growth, in order to see the effects of alternative patterns of population growth on world food supply. Sadie (1987) compared the effects on the size and composition of the labor force and on the school age population of the expected future growth of the population of South Africa to what would happen if zero population growth (total fertility rate equal to 2.1) and the class structure of the population of Canada were in effect in South Africa.

Projections are often done in order to estimate the size of the future school-age population or of the labor force, as an aid in planning (Sadie, 1991; Sadie & Martins, 1994). Udjo (1998) estimated the effect of high versus low future fertility assumptions on the demands for housing, education and health care in Botswana in 2011, as projected from 1991.

(5) Projections as Counterfactual History. At times the purpose of a projection is counterfactual history. This kind of projection is never a forecast or prediction. This kind of projection says,

“If the past had been different, this is what the population would have looked like today or at some other date.”

Projections are done to assess the impact of some past event and to answer questions such as: What would the Afrikaans-speaking population of South Africa have been in the late 1970s if the Anglo-
Boer War had never occurred (Sadie, 1979)? Often when some event has a large impact on mortality, the question becomes: How many excess deaths were there in World War (Andreev et al., 1990)? or, How many excess deaths were there due to Stalin’s regime in the 1930s (Anderson & Silver, 1985)? or, How many people died due to the Khmer Rouge in Cambodia (Heuveline, 1998)? or, How many excess deaths were there during a severe heatwave (Rooney et al., 1998)? Sometimes the purpose of this kind of projection is to show the magnitude of a crime. Testimony based on demographic assessments of excess deaths in former Yugoslavia constituted part of the evidence in war crimes trials (Ball & Asher, 2002).

(6) Projections to Determine Effects of Causes of Death Other than in a Disaster or a War. Projections also are done to determine the effects of causes of death that are not the result of a disaster or war. Similar to purpose (5), this is not a prediction or forecast. This kind of projection says,

“If a given cause of death were eliminated or reduced by some amount, what would the population look like?”

White & Preston (1996) estimated what the population of the United States would have been at the end of the twentieth century if mortality had remained at the level it was in 1900. A similar question is: What would the population of a given country be if cancer were eliminated? When the effects of elimination of a particular cause of death are considered, often the impact on the expectation of life at birth or the number of deaths averted are estimated rather than the effect on the size and composition of the population as a whole (Bustan et al., 1989; Conti et al., 1999; Hossain et al., 1998; Lai & Hardy, 1999). Evans et al. (1997) estimated the number of child deaths from malaria that would be prevented if the government provided subsidies for insecticide-impregnated mosquito nets. He then calculated whether this would be a cost-effective way to lower child mortality in comparison to other uses of government funds.

(7) Projections in Evaluation or Assessment of Program Effectiveness. Projections are also used in program evaluation or assessment of program effectiveness. This is a kind of counterfactual history. This kind of projection says,

“If the given program had not been implemented, what would the population have looked like?”

An example of the use of this kind of projection is evaluation of family planning programs. Questions to be answered include: What would the population of a country have been if a contraceptive program had not been implemented? Often in assessment of fertility programs, rather than doing a complete population projection, there is an estimate of the number of births averted due to the program (Chaudhry, 1988; Forrest & Singh, 1990). If women and couples had already begun to voluntarily limit their fertility, this estimate of births averted is the difference between the number of births that actually occurred and an estimate of how many births there would have been if fertility limitation had continued to increase according to some schedule even without the contraceptive program (Freedman & Takeshita, 1969; Potter, 1971).

WHY POPULATION PROJECTIONS ARE USEFUL IN ASSESSING THE IMPACT OF HIV/AIDS

Population projections have been the focus of a great deal of attention in assessing the impact of HIV/AIDS for several reasons. First is that HIV/AIDS not only contributes to mortality, but is generally thought to have a fertility-inhibiting effect in HIV-positive women.
Second, is that the age pattern of mortality from HIV/AIDS includes high death rates within the working ages, which include the reproductive ages. The effects of HIV/AIDS on people in their most productive years and who have the main responsibility for the welfare of others has generated more concern than would a similarly serious epidemic whose victims did not play such a crucial role in society. There has been great concern about HIV/AIDS possibly decimating the labor force of various countries (Anonymous, 2000, 2001; Paul, 2001). A special concern has been the depletion of the number of key professionals, such as teachers (Inambao, 2002; Lund, 2002; World Bank, 2002). The implications for employee benefit payments (Doyle, 1997) as well as for other costs to businesses whose employees become HIV positive have been a subject of great interest (Foster, 1996; Moore, 1999).

Thus, HIV/AIDS affects many components of population growth and has a different age pattern of mortality than most diseases. For men, death from violence and from alcohol and tobacco-related causes have a somewhat similar pattern of age at death, as does tuberculosis for both sexes, but most other diseases have their largest effects at the youngest ages and at older ages, well past women’s reproductive ages and past the normal working ages.

A population projection, in which the effects of fertility and mortality changes can be discerned, is an appropriate tool for assessing the complex impacts of HIV/AIDS (Bongaarts, 1989). In addition, due to the toll of HIV/AIDS on the working-age population, estimates of the population by age and sex that include the effects of HIV/AIDS are important for estimates of the future of the economy and labor productivity. Thus, projections have been used to discern the effects of HIV/AIDS on expectation of life at birth, but also on the percentage of children who are orphans (Johnson & Dorrington, 2001; Gregson, Garnett et al., 1994). Projections could provide additional information about the likely effect of HIV/AIDS on the labor force.

**WHAT ARE THE PURPOSES OF PROJECTIONS OF THE POPULATION OF SOUTH AFRICA INTENDED TO ASSESS THE EFFECTS AND IMPACT OF HIV/AIDS?**

One purpose of these projections is to forecast South Africa’s population. Because HIV/AIDS is expected to have a major impact on South Africa’s future population, it is reasonable for a population forecast for South Africa to take HIV/AIDS into account.

Another aspect of the projections intended to assess the effects and impact of HIV/AIDS is clearly counterfactual. Since HIV/AIDS is a major cause of mortality in South Africa and is certain to remain so for some time in the future, a projection of the population of South Africa with fertility and mortality unaffected by AIDS is not a prediction of the future. However, that counterfactual projection is necessary in order to assess the impact of HIV/AIDS.

A comparison of projections that include the effects of HIV/AIDS with projections without HIV/AIDS can show the likely future impact of HIV/AIDS on population characteristics (such as the total fertility rate or the expectation of life at birth) and on population size and structure (such as the proportion of the population in the working ages or the sex ratio at various ages). If the projections are done for subpopulations (such as Africans and non-Africans) then the effects of HIV/AIDS on those subpopulations can be assessed.

Population projections could also be used to model the likely effects of behavioral changes in the population, of policies that the government might implement, or of possible medical breakthroughs.
WHAT DO WE KNOW FROM POPULATION PROJECTIONS WITH ATTENTION TO HIV/AIDS FOR OTHER COUNTRIES?

Population projections for countries other than South Africa that have included the estimated effects of HIV/AIDS have yielded mixed results. Although some have predicted population decline and substantial effects on the age structure (Anonymous, 1991; Sanderson et al., 2001; Shemeikka, 1999), others have predicted relatively little effect on the overall size and age-sex composition of the population (Brunborg, 1995; United Nations, Population Division, 1993). Although projected population growth rates are predicted to decrease, this does not always result in predicted decrease in the size of the total population (Robinson & Marindo, 1999). The United Nations estimates from 2000 found predicted population decline by 2015 in few of the 35 African countries with a substantial level of HIV/AIDS. However the United Nations found the estimated population size to be 10% lower than it would have been without HIV/AIDS (O’Neill & Balk, 2001). All projections have found declines in the expectation of life at birth and an increase in deaths as a result of HIV/AIDS.

Table 1 presents a simple example of how a large increase in the number of deaths, for example to men in their early 30s, could have a fairly small effect on the size and composition of the population. The number of deaths and the number of survivors under two scenarios is shown, first with normal but high mortality, and second with a doubling in the number of deaths, due to the effects of HIV/AIDS. In this example, the “normal” mortality assumption is that for males in Coale-Demeny North Model Life Tables with expectation of life at birth of about 45 years (level 12) (Coale & Demeny, 1966: 231).

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
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<tr>
<td>Normal, but High Mortality</td>
<td>Mortality Doubled Due to AIDS</td>
</tr>
<tr>
<td>Number of Men Age 30 in 2005</td>
<td>65002</td>
</tr>
<tr>
<td>Number Who Die Before 2010</td>
<td>2758</td>
</tr>
<tr>
<td>Survivors to Age 35 in 2010</td>
<td>62244</td>
</tr>
<tr>
<td>Percentage of Men Who Survive from Age 30 in 2005 to Age 35 in 2010</td>
<td>96%</td>
</tr>
<tr>
<td>Percentage Increase in Number of Deaths Due to AIDS</td>
<td></td>
</tr>
<tr>
<td>Percentage Decrease in Number of Survivors from Age 30 to Age 35 Due to AIDS</td>
<td></td>
</tr>
</tbody>
</table>

Although the number of deaths increased from Scenario 1 to Scenario 2 by 100%, the number of survivors from age 30 to age 35 is only 4% less in Scenario 2 than in Scenario 1. This is because even in high mortality populations, those over age 10 and under about age 60 have relatively low
death rates. Thus death rates can increase by a large percentage without having a large impact on the number of survivors.

**PROJECTING THE SIZE OF THE HIV-POSITIVE AND THE AIDS POPULATION**

The impact of HIV/AIDS on the size and age-sex structure of South Africa’s population will not be definitely known until more work has been done. However, whether the effects are large or small, an important issue for the purposes of policy is the status of the living population.

Among the living, the number of people and characteristics of the population with active AIDS is especially important. These people can be considered disabled, since they are unable to be fully functioning members of society. Also the social and economic costs of the AIDS epidemic are strongly related to the characteristics of the active-AIDS population.

Most of the major projection programs that consider the impact of HIV/AIDS divide the population into those who are HIV negative, those who are HIV positive but without active AIDS, and those with active AIDS. Alternative projections should include examination not only of the robustness of the estimates of the number of those alive by age and sex but also of the robustness of the estimates of the living population by HIV/AIDS status.

To the extent that projections by HIV/AIDS status are robust, they are useful for policy planning. In addition, the effects of possible policies or behavioral changes on the population by HIV/AIDS status are important in assessing alternative plans for policies and public campaigns.

**WHY THE FUTURE COURSE OF “NORMAL” AND HIV/AIDS RELATED FERTILITY AND MORTALITY ARE IMPORTANT**

Population growth between two dates is the result of the balance between the number of births in excess of deaths and of the number of migrants into the country over the number of migrants out of the country. This is described by the population balancing equation:

\[ P_2 = P_1 + B - D + I - E \]

where:
- \( P_2 \) = Population at Time 2
- \( P_1 \) = Population at Time 1
- \( B \) = Births between Time 1 and Time 2
- \( D \) = Deaths between Time 1 and Time 2
- \( I \) = Immigrants between Time 1 and Time 2
- \( E \) = Emigrants between Time 1 and Time 2

The number of births is affected by fertility desires on the part of women and couples, by contraceptive use, by abortion, and by fertility-inhibiting effects of diseases such as HIV/AIDS. Deaths are the result of non-AIDS diseases, accidents, and violence, as well as HIV/AIDS. Anything that modifies any of these components of population growth affects how large or how small the population is at Time 2 compared to its size at Time 1.

In projecting the population from Time 1 to Time 2, with a view both to estimating the size and characteristics of the population at Time 2 and with a view to assessing the impact of HIV/AIDS on the population, assumptions about non-AIDS and AIDS mortality are important. Also assumptions
about the course of fertility between Time 1 and Time 2 and how fertility in the time interval is
affected by HIV/AIDS is important. Alternative assumptions about migration can also make a
difference.

In any population, there is some uncertainty about future trajectories of fertility and mortality. In the
case of mortality, it is safe to assume that individuals and families would prefer lower mortality to
higher mortality. Although the course of mortality change in the modern world has generally been
toward lower mortality, this has not been true at all times for all ages. Modern behaviors, such as
smoking, alcohol consumption, and lack of exercise, can contribute to a rise in mortality at least for
some ages. Thus, the future course of non-AIDS mortality is not obvious and is dependent not only
on governmental policies and the availability of health care, but also on life style choices by
individuals. Thus, even for future non-AIDS mortality, a range of trajectories is possible.

The future of fertility is even more uncertain. While everyone wants lower mortality, sometimes
individuals and families desire lower fertility, and sometimes they desire higher fertility. Throughout
the world, once a substantial portion of the population can effectively control their fertility, fairly
large fertility fluctuations can occur, in response to changing economic or political circumstances.
Fertility can decline in times of economic hardship (Ranjan, 1999) and then increase when the
situation improves.

Thus it is important to do alternative projections that cover the range of likely fertility and mortality
scenarios, even apart from the effects of HIV/AIDS.

In the area of HIV/AIDS and its impact on mortality and fertility there are also important decisions to
be made. To project the effects of HIV/AIDS on mortality, there must be some assumption about the
course of the spread of the disease. This rate of spread is also influenced by actions both on the part
of the government and on the part of individuals. Even if a given scenario of unchanging (or
changing) behaviors by the population or by the government is posited, there is still uncertainty about
how this will be manifested in HIV/AIDS age-specific mortality rates. If different scenarios of
population or government behavior are to be investigated, this leads to alternative projections.

To assess the impact of HIV/AIDS through projections, a projection in which age-specific mortality
and fertility are not influenced by HIV/AIDS is compared with a projection in which mortality and
fertility are affected by HIV/AIDS. If alternative scenarios of HIV/AIDS are considered, then
alternative projections with HIV/AIDS can be compared to the projections without HIV/AIDS. Thus,
the influence of HIV/AIDS on population size and on other characteristics of the population in a
projection will depend on the assumed future course of non-AIDS mortality and fertility.

**The Future Course of “Normal” Fertility and Mortality**

In a cohort-component projection, an explicit age-specific mortality schedule by sex and an explicit
age-specific fertility schedule are used for each time period of the projection, which is usually a five-
year interval. The schedules used can be held constant throughout the entire time period of the
projection of twenty or thirty years, or the schedules can be changed for each five-year projection
period. In order for the projection to be assessed, it is important for the age-specific schedules that
are used for each projection interval to be made available for examination. A rationale for why the
schedules were or were not changed over the course of the entire projection period is also important.
Fertility and mortality assumptions will then be transparent.
The Future Course of “Normal” Fertility

The future “normal” course of fertility in South Africa is an extremely important issue. Variation in the fertility assumptions in a projection typically makes much more difference in the projected population than does variation in mortality assumptions.

Fertility is very important because every person is born at age zero and contributes directly to population size. Also, every birth adds to the base that has the opportunity to pass through the reproductive ages and have children.

Mortality has much less effect on population growth, since when a person dies after the reproductive ages, that person’s lifetime fertility is unaffected. When a person dies partway through the reproductive ages, there is some effect on population growth. Only when a child dies before the reproductive ages is there an effect on population growth that is similar to fertility. If a child dies one minute after being born, the effect on population growth is the same as if he or she had never been born. In virtually all populations, even very high mortality populations, the chance of dying between about age ten and about age twenty is extremely low (Anderson, 2002). All children are born at age zero, and the higher fertility, the younger the population age distribution. Since people die at all ages, especially the very young and the elderly, mortality has a smaller and more mixed effect on the age distribution of the population than does fertility (Coale, 1964).

The large impact of fertility on projections is why when the United Nations produces population projections for each country of the world, the High, Medium, and Low versions differ in assumed future fertility but do not differ in assumed future mortality. The United Nations takes this approach not because they know what the future course of mortality will be, but because variation in likely future mortality typically makes fairly little difference in the projected population.

In the United Nations classifications, South Africa in the early 21st century is an intermediate fertility country. In preparation for the production of World Population Trends 2002, the United Nations revised their fertility assumptions for projections of the intermediate fertility countries. Whereas earlier the U.N. only projected fertility in the future in current intermediate fertility countries to fall to replacement level, given the large number of developed countries that have maintained below replacement fertility for some time, the intermediate fertility countries are now projected to eventually reach below replacement fertility (United Nations, Population Division, 2002).

On the other hand, Swartz (2002) argues that it is plausible that the fertility of African women in South Africa could rise in the future. He argues that under apartheid, the political situation could have led women to have fewer children than they would have had otherwise. Fertility of African women in South Africa has been lower than that of African women in other sub-Saharan African countries for some time, and it is not clear why African women in South Africa would have desired fewer children than African women in other countries. With a non-racial government in South Africa and with a decrease in violence, many African women could feel that the time has come for a higher level of childbearing. This would be somewhat similar to the large rise in fertility in the United States and other countries after World War II. The Baby Boom in the United States was caused both by delayed childbearing from women who had postponed childbearing during the Depression of the 1930s and by an increase in desired family size (Anderson, 2002: 445-447).

The range of future fertility assumptions for South Africa used in projections is likely to be the most important element of the projected size of the population of South Africa. Heuveline (1997) concluded that in projecting the size of sub-Saharan African populations that are affected by HIV/AIDS, assumptions about what is likely to happen to fertility, including the effects of HIV/AIDS on fertility, play a larger role than any particular assumption about the spread of the HIV epidemic.
The Future Course of “Normal” Mortality

Conclusions about the future course of normal (non-AIDS) mortality are complicated by uncertainty about the level and age pattern of non-AIDS mortality in South Africa and the likely future effect on mortality of unhealthy behaviors that are not directly related to HIV/AIDS.

Uncertainly About the Level and Age Pattern of non-AIDS Mortality

There is uncertainty about the level and age pattern of mortality, including non-AIDS mortality, in South Africa. This is partially because in 1996 in South Africa as a whole, 67% of all deaths were estimated to be registered, and in rural areas 38% were estimated to be registered (Statistics South Africa, 2000: vi). In addition, in 1996, 13% of registered deaths for males and 17% of registered deaths for females had an ill-defined cause (Statistics South Africa, 2000: x). Mostert (1988) found that the age pattern of mortality among non-Africans in South Africa was different from that in developed Western countries with a similar expectation of life at birth; the non-African South African population had higher mortality in the adult ages (and thus lower mortality at younger and very old ages) than the Western countries with the same expectation of life at birth.

Effects of Smoking, Alcohol, and Overeating on Mortality

Through much of the developing world, unhealthy behaviors common in the developed countries, such as smoking, high levels of alcohol consumption, and consumption of high calorie foods with little nutritional value, have increased (Bah, 1993; Gwatkin, 1980; Walker, 1996; World Health Organization, 1999). These behaviors are expected to contribute to higher adult mortality for both sexes (Beaton, 1997; Gunawardene, 1999), as they have already in many parts of the world (Nizard & Munoz-Perez, 1993; Shkolnikov & Mesle, 1996; Shkolnikov et al, 1997). After World War II, increased smoking led to a rise in age-specific mortality rates of men in the older working ages in many Western countries (Preston, 1970), and the mortality effects of smoking continue to be a serious problem in most developed countries (Peto et al., 1994). With economic improvements in formerly underprivileged parts of the population, overeating and obesity can lead to, complicate, or increase the death rates from many serious health problems, including diabetes (Abid et al., 2000; Jung, 1997; Popkin et al., 1997; Tierney et al., 2001; World Health Organization, 1998; Zohoori et al., 1998). Diabetes seems to be a serious and increasing problem in South Africa (Levitt et al, 1997; Temple et al, 2001). In 1998, 30% of women in South Africa were obese (South Africa, Department of Health, 2002: 247).

These behaviors and their mortality consequences have an especially large effect on men, since men tend to smoke and drink alcohol more than women (Waldron, 1997). However, the consequences of these behaviors by women can have additional effects through the birth of less healthy babies, with increased chance of infant or child death. For example, smoking by pregnant women has been found to contribute to the chance of a low birthweight newborn (Al-Awadi & Amin, 1992; Bener et al, 1996), smoking by the mother also increases the chance of early neonatal death (Fourn et al., 1999; Gray, Ferraz et al., 1991) and other complications for the newborn (Odendaal et al., 2001), and maternal alcohol consumption has been found to be related to malnutrition among children (Setswe, 1994). High levels of alcohol consumption and associated fetal alcohol syndrome have been a source of concern in South Africa (May et al., 2000) and alcohol consumption with resultant fetal alcohol syndrome could increase in the future (Anderson, 2003).
The Direct Effects of HIV/AIDS on Future Fertility and Mortality

In doing a projection that includes the effects of HIV/AIDS, there have been various approaches as to how to divide the population by susceptibility to HIV and by HIV/AIDS status. In each of the three approaches described briefly below, transition probabilities between risk groups, from each risk group to being HIV positive, and in the case of the IIASA model, between HIV-positive groups are required. For each group there also needs to be a risk of death.

(1) Dorrington et al. (2001: 51) divided the population into four groups from greater to lesser risk of infection: (1) Sex workers and their clients; (2) Those regularly infected with sexually transmitted infections; (3) Those exposed to risky sexual behavior but without sexually transmitted infections; (4) Those not at risk of HIV infection. There also is an HIV-positive group. Transition probabilities between risk groups and from each risk group to becoming HIV positive need to be assigned. If this approach is used, there need to be decisions about the risk groups into which the population will be divided and what the transition probabilities between groups will be.

(2) In the International Institute for Applied Systems Analysis (IIASA) project on Population Development and Environment in Botswana, the population is divided along many dimensions. It is divided by HIV status (HIV negative; HIV positive, asymptomatic, and not on medication; HIV positive, asymptomatic, and on medication; and AIDS, i.e., symptomatic); by number of years since HIV infection for those who are HIV positive; by sexual behavior risk group for those who are HIV negative; and by onset of sexual activity (for young women and men) (Sanderson & Hellmuth, 2001).

(3) The UNAIDS EPP Model (UNAIDS, 2002: 38), like the IIASA model, divides the non-infected population into two groups, those at risk and those not at risk.

Whatever approach is used, there needs to be a decision about the assumed distribution of time from becoming HIV positive to full AIDS and from full AIDS to death. Empirical work on the time from infection to AIDS among adults has found a range for the median or average time of 6.1-16.1 years (Alcabes et al., 1994; Buchbinder et al., 1994, 1996; Chevret et al., 1992; Chiarotti et al., 1994; Downs, Ancelle-Park et al., 1991; Hendriks, Clark et al., 1993; Hendriks, Medley et al., 1992; Hendriks, Satten et al., 1996; Law, 1994; Operskalski et al., 1995; Salamini et al., 1992; Veuglers, 1994). There is evidence that the lag from becoming HIV positive to AIDS on average is 1-2 years shorter for those in Africa than for those in Europe or the United States (Grant et al., 1997). For estimates relevant to sub-Saharan Africa as a whole Gregson, Garnett et al. (1994: 457) assumed an average period from HIV infection to development of AIDS of eight years for adults, and a mean period from acquisition of AIDS to death of one year, for a total average lag from infection with HIV to death from AIDS of nine years. The U. S. Bureau of the Census in its projections has assumed a median time from HIV infection to development of AIDS of 7.5 years and from AIDS to death of 1 year, for a total lag of 8.5 years, while UNAIDS assumes a lag of 10 years from HIV infection to AIDS (Hunter & Williamson, 2000: 23). The UNAIDS program assumes a period of 8.6 years for males and 9.4 years for females in developing countries (UNAIDS, 2002: 43).

Children have been found to progress from becoming HIV positive to AIDS more rapidly than adults, implying that the average lag time for children in a model should be shorter than that for adults. For those infected from birth the time to AIDS has a range of 1-6.3 years (Auger et al., 1988; Commenges et al., 1992; Downs, Salamini et al., 1995; Jones et al., 1989; Lui et al., 1988; Oxtaby et al., 1992; Pliner et al., 1996). The UNAIDS program default has a median time from birth to death from AIDS of about 1.5 years (UNAIDS, 2002: 44).

Another issue that needs to be resolved is what assumption or range of assumptions should be used for the mother to child transmission rate for HIV-positive mothers. There have been estimates of this
as 13-32% in developed countries and 25-48% in developing countries (Bryson, 1996; Dabis et al., 1993). The UNAIDS model (UNAIDS, 2002: 47) uses a rate of 32%, although this can be changed in the model.

It is often assumed that being HIV positive depresses a woman’s fertility, although empirical work has shown mixed results. Gregson and others found no clear results but concluded that HIV/AIDS slightly reduces fertility (Gregson, 1994; Gregson, Zhuwau et al., 1997). Ainsworth et al (1995), Gray, Serwadda et al (1997), and Carpenter et al. (1997) found that HIV/AIDS reduced fertility. The UNAIDS model (2002: 48) assumes that fertility is 50% higher among 15-19 year old HIV-positive women than among 15-19 year old HIV-negative women and that among women age 20-49, fertility is 20% lower among HIV-positive women than among HIV-negative women.


Much of the work on estimating the impact of AIDS on death rates is based on the difference between the observed number of deaths and the age pattern of these deaths in comparison to the expected number and age pattern of deaths from non-AIDS mortality (Dorrington et al., 2001). AIDS mortality is distinguished by relatively high death rates among the older adult ages (approximately age 30-50) and among infants and children. To the extent that death rates in these ages are also increasing due to the effects of negative health behaviors such as smoking and alcohol consumption, rather than from HIV/AIDS, the impact of HIV/AIDS on mortality could be seriously misestimated.

HEALTH BEHAVIORS, OTHER CONDITIONS, RISKS OF BECOMING HIV POSITIVE, AND THE COURSE OF HIV/AIDS

There is evidence that unhealthy behaviors, such as smoking and drinking, increase the chance that a person will become HIV positive (Allen et al., 1993; Dowe et al., 2001; Gwati et al., 1995; Mbulaiteye et al, 2000; Nopkesorn et al., 1998; Tengia-Kessy et al., 1998). Based on research in South Africa, it has been found that among those who have TB and then become HIV positive, the speed of progression from HIV to AIDS and from AIDS to death is more rapid (Badri et al., 2001), and death rates from TB are increased (Connolly et al., 1998; Corbett et al., 2000). Also being HIV positive increases the chance of acquiring TB due to a weakened immunologic system (Churchyard & Grant, 2000). In South Africa, TB is the most common opportunistic infection related to HIV/AIDS (Morris & Williamson, 2001).

There need to be decisions about whether and in what way interactions of HIV/AIDS with negative health behaviors and pre-existing conditions, such as tuberculosis, will be incorporated in the projection.

INTERNATIONAL MIGRATION

In doing projections for South Africa, it needs to be decided whether and in what way international migration is incorporated. It is thought that persons entering South Africa from other African countries have been sources of transmission of HIV. Also, it is thought that South Africa has experienced net emigration of non-Africans in recent years and net immigration of Africans.
Incorporation of migration into population projections has been very difficult. Some projections for South Africa have incorporated international migration assumptions, especially for the White population (Sadie, 1973; van Aardt et al., 1999) and for the foreign-born African population (Sadie, 1988). However, several analysts have considered making a migration assumption for their projections but have decided that there was either no indication of likely substantial international migration or no firm basis for any assumption (Lutz et al., 2001; Mostert & van Tonder, 1987; Udjo, 1999). Regional projections and extrapolations of population for South Africa have sometimes included assumptions about migration into and out of the given region (Kok, 1982; van Tonder, 2000).

Assuming no net immigration in projections for South Africa would not necessarily be the wrong decision, even though recent experience shows a non-trivial amount of international migration (Kok, forthcoming 2004). If international migration is not included in the projection, it should be explicit rather than being a default.

**WHY SEPARATE PROJECTIONS FOR AFRICANS AND NON-AFRICANS ARE IMPORTANT**

There are several reasons why it is important for the projections to be carried out separately for the African and non-African population of South Africa. The fertility and mortality schedules for the African and non-African population are very different, as are likely changes in the future. The immigration situation for these populations is also different now and likely to remain different in the future, with the African population experiencing net immigration and the non-African population experiencing net emigration.

Although there are large gaps in knowledge of the extent of HIV/AIDS among the African population, there is even less information about the extent of HIV/AIDS among the non-African population. Perhaps alternative reasonable assumptions about the non-African population will make little difference in the overall projections. If so, this lack of knowledge about the non-African population would not be a serious limitation.

Some might suggest that the non-African population be further divided into the Coloured population, the Asian population, and the White population. The non-African population as a whole is about one-quarter the population of South Africa. The White and the Asian populations have generally similar fertility and mortality in comparison to the African population. The Coloured population has mortality and fertility characteristics intermediate between the African population and the Asian and White populations. It needs to be decided whether there is a basis for projections of groups within the non-African population separately for the purpose of assessing the impact of HIV/AIDS.

**CHOICE OF A BASE POPULATION FOR PROJECTIONS**

The size and the age-sex composition of the population of South Africa at the time of the 1996 Census has been a subject of great controversy (Simkins 1999a). As Lutz et al. (2001: 3-4) and Dorrington et al. (2001: 23) point out, the size and age-sex composition of the base population for South Africa used by different groups in making projections have differed greatly. These differences have mainly resulted from different estimates of the actual population of South Africa at the time of the 1996 Census. Even if data from the 2001 Census are used for new projections, similar issues are likely to arise. There must be a decision about the size and age-sex-ethnic composition of a base population used for a projection.
PROCEEDING AFTER RANGES OF ASSUMPTIONS HAVE BEEN IDENTIFIED

This paper suggests determining ranges of assumptions for a wide variety of factors that influence the results of a population projection. It is not suggested that projections that include all the possible combinations of assumptions actually be carried out. That would be an unmanageable task. Rather it is suggested that for each factor considered, preliminary analysis be undertaken to determine whether the reasonable range of assumptions for that factor is likely to make a substantial difference in the outcome of a projection, when other factors are held constant. If variations in a given factor make little difference, then the work can proceed with one reasonable value assumed for that factor. Thus, the preliminary analysis is actually a sensitivity analysis that should lead to final projections being carried out under a manageable number of combinations of assumptions.

RECOMMENDATIONS FOR FUTURE PROJECTIONS INTENDED TO ASSESS THE DEMOGRAPHIC IMPACT OF HIV/AIDS

1. Cohort-component projections should be done for the two sexes separately.

2. The age-specific fertility and mortality schedules applied for each five-year period should be explicitly stated.

3. The fertility and mortality schedules used to project a normal future should result from a serious consideration of the likely possible future variation in these schedules.

4. The effects of AIDS on fertility and mortality schedules used in the projections should result from serious consideration of the likely future effects of AIDS on these schedules. It needs to be decided whether to take interactions between non-AIDS morbidity and HIV-positive status into account in estimating mortality schedules.

5. All assumptions in the projections should be clearly stated.

6. There needs to be a decision whether projections that take HIV/AIDS into account concerning the size and composition of the estimated active AIDS population are stable enough to influence policy planning.

7. The projections produced should encompass a range rather than a single projection without AIDS and a single projection with AIDS.

8. The projections should be done separately for the African and non-African populations and then combined at the end to assess the overall result.

9. It must be decided whether and how to incorporate international migration.

10. The size, age-sex, and ethnic composition of the base population need to be decided.

11. Preliminary analysis can reveal whether employing a range in a given assumption makes a substantial or a trivial difference in a projection. If it makes a trivial difference, then a single value can be used for that assumption in further projections. Thus, the final number of projections presented would be less than the maximum number possible.
THOUGHTS ABOUT FURTHER WORK

There are some issues that should be considered in planning further work beyond the population projections discussed here. These issues are very complicated, but it would be worthwhile to think about how they could be approached.

A broader concern than the HIV/AIDS status of the surviving population is the disability status of the population by age and sex. If a person has active AIDS, he or she can be considered disabled. However, there are a wide variety of other factors that lead to disability, even among the working-age population in South Africa, as well as in other countries in the developing world. The most important non-AIDS types of disability need to be identified. They might include non-AIDS related TB, non-AIDS-related respiratory conditions, chronic malaria, trachoma, and other types of parasitic infestation.

It would be valuable to project the population with these non-AIDS disabilities as well as the population by HIV/AIDS status so that the entire picture of the likely future South African population could related to disability status and to the ability to function fully in society could be known.
REFERENCES


