POPULATION PROJECTION IN KENYA:

AN APPLICATION OF THE STABLE POPULATION MODEL

BY

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DECLARATION

This project is my original work and has not been submitted either wholly or partially to this or any other University for the award of a degree

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DEDICATION

This work is dedicated to my loving parents;

Timona and Esther Masafu

for their selfless support.

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Glory be to our Almighty God for His wholesome grace and favour that saw me through ALL, to the completion of this project; I bless His Holy name.

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ABSTRACT.

The general objective of the study was to project the Kenyan population to stability. The study specifically looked at obtaining the projection matrix for Kenya, estimating the stable age structure for Kenya and comparing the population size, rate of natural increase and the net reproductive rate of the stable population with the current reported and related demographic indicators. The study data was obtained from the1999 Kenya population census.

The study is arranged in five chapters where chapter one deals with the introduction, the problem statement, objectives, justification, scope and limitation. Chapter two presents the literature review while chapter three handles the data source and the method of analysis, specifically giving an in-depth description of the matrix method of population projection. Chapter four presents the findings of the study and finally chapter five gives the summary of the findings, conclusions and recommendations both for policy and for further research.

The major findings of this study are that under the fertility and mortality rate of the base population of 2000, the Kenyan population would stabilize by the year 2090 with a youthful age structure. The dominant latent root of this stable population is 1.183, which gives the intrinsic rate of natural increase of 0.22% per annum and the net reproductive rate of 1.0636.The dependency ratio of the Kenyan population will remain high with just a slight decline of 5% from 76% in 2005 to 71% in the year 2090 at stability. The total population will increase rapidly to 32.4 millions, 41.8 millions, 62.2 millions, 97.6 millions, 109 millions and 180.6 millions in the years 2005, 2020, 2050, 2090, 2100 and 2145 respectively. Over the same period, the mean age of the female population will be

23.43 years, 25.33 years, 28.01 years, and 27.95 years 28.02 years, 28.01 years and 28.00 years respectively. This is a clear indication of the ageing population.

A youthful age structure poses greater challenge to the government and presents such high dependency ratios which enslave the working few to support the rest of the population. The government is forced to invest in consumer projects like education, food security, and health, housing and general infrastructure rather than in income generating projects like industries. Policies should be set up and reinforced to ensure that the economic growth rate is increasing in direct proportion to the population growth rate in order to achieve national development. The government should vigorously invest in the efforts to reduce the fertility levels by supporting family planning programs for this will encourage the population to age and stabilize with a columnar age structure which usually has a low dependency ratio.

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CHAPTER ONE: INTRODUCTION AND THE PROBLEM STATEMENT

1.1 Introduction

A population which experiences no gains or losses through migration and which experiences an unchanging age schedule of death rates and birth rates, has an age distribution, birth rate, death rate, and rate of increase that do not change. No matter what its initial age distribution, it will eventually develop a constant age distribution and increase in size at a constant rate. Such population is called a stable population (Smith and Keyfitz, 1977 and Muir, 2002) reflected by the level of fertility and mortality. This population has a constant age structure and it produces simple relationships among demographic parameters such as births are equal to deaths and population growth corresponding to the age structure.

The age structure is the absolute number of individuals of each age group alive within a population. It is affected by births, deaths, emigration and immigration. High rate of population growth produces a youthful population having a broad based pyramid age structure. Such a structure is characterized by high net reproductive rate, which leads to high demand for social amenities; education, health and food. The developing countries have this kind of age structure and are focusing on steps to encourage stabilization. These steps include meeting the unmet demand for contraceptives, decreasing demand for large families and decreasing population momentum (the disparity between actual age distribution and the eventual stationary age distribution). By contrast, the developed countries have an ageing population with columnar age structure where we have a larger proportion of old people than the young. The problems associated with old age have therefore to be addressed. Labor force supply becomes a problem that necessitates the employment of the elderly people to meet the shortfall. Epidemiological transition also takes place in such a population where chronic and degenerating diseases become the major cause of death rather than the parasitic and infectious diseases. It is important to analyze the population age structure to meet varying needs. This study uses the stable population model to project the Kenyan population to stability.

1.2 Problem statement.

A number of population projections have been done in Kenya. Wekesa (1989) projected the school population and analyzed its implications to education planning. Rafiq (1992) projected the future population of Kenya to the year 2040 using the component method. Central Bureau of Statistics (2002) projections were done to the year 2020 using the component method of projection. All these projections neither give an indication to when the Kenyan population would stabilize nor the corresponding age structure.

This study demonstrates the use of matrices on projecting population and obtaining the stable age structure. The aim is to give an indication to when the population of Kenya would stabilize under the current mortality and fertility rates and the resultant age structure at that point in time. Demographic indicators such as the natural rate of increase and the net reproductive rate are also obtained which provide a basis for formulation of feasible population policies on manpower potential and utilization, education, environment, human settlements, health, agricultural activities and other development concerns.

This study addresses the following research questions;

1. When would the population of Kenya stabilize and with what age structure at the current level of fertility and mortality?
2. What variations exist between the population size, rate of natural increase and the net reproductive rate of the stable population with the current reported and related demographic indicators?

1.3 Objectives of the study

The general objective of this study is to project the population of Kenya to stability.

The specific objectives are:

1. To obtain the projection matrix for Kenya.
2. To estimate the stable age structure for Kenya.
3. To compare the population size, rate of natural increase and the net reproductive rate of the stable population with the current reported and related demographic indicators.

1.4 Justification for the study

Although population projections exist for Kenya, the time of stability and its age structure are not known. With the projection matrix we can project the population of Kenya to know when it can stabilize. A stable matrix can also be obtained by the condensation of the projection matrix. This is an important demographic tool from which we can derive other demographic indicators such as spectral components, latent roots, reproductive value, intrinsic growth rate and net reproductive rate which tells much about the epidemiological aspects of the population as well as the reproductive needs of the populace.

Knowing when the population may stabilize helps in the estimation of the age structure at that point in time and it also facilitates the preparation for the challenges of the ageing population. It is important, too, for the government to know the annual population increase for effective planning and allocation of resource endowment in the country. Already the Kenyan government has realized the dynamics of old age and in this year's 2004 annual budget, provision has been made to increase pension schemes. Taxable pension amount was also increased. Chronic and degenerating diseases like cancer are also on the increase and this makes life insurance premiums to be quite high. Despite the prevailing death rates the government is making efforts to provide free Medicare, free education, increased advocacy in the reduction of the spread of HIV\AIDS and the commitment in the creation of employment opportunities. These efforts will improve the quality of life and hence many people will live to old age.

1.5 Scope and limitation

The study used secondary data from the1999 Population Census. It utilized the refined method of matrix estimation to obtain the projection matrix for Kenya. The rate of natural increase and net reproductive rates are the only indicators that were derived from the dominant latent root of the stable matrix. The assumption that probability of survival and the age specific fertility rates will remain constant is limiting. However, this assumption facilitates the projection process.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction.

An understanding of the concept of the stable population, the age structure and its dynamics as well as the matrix method of population projection is crucial in this study. To facilitate this understanding, the literature reviewed in this section is organized under the headings; concept of stability, age structure and background to projection methods.

2.2 Concept of stability.

A population which experiences no gains or losses through migration and which experiences an unchanging age schedule of death rates and birth rates, has an age distribution, birth rate, death rate, and rate of increase that do not change. No matter what its initial age distribution, it will eventually develop a constant age distribution and increase in size at a constant rate. Such population is called a stable population (Smith and Keyfitz, 1977 and Muir, 2002). This population has a constant age structure and it produces simple relationships among demographic parameters such as births are equal to deaths and population growth corresponding to the age structure.

A stable population has a unique age distribution that is inherent in the fertility and mortality schedules of generation. With time the age distribution converges to a constant limited age distribution and the population eventually 'forgets' its initial age distribution. This is the ergodicity property in demography; the tendency of the population to forget its initial age distribution (Keyfitz, 1968). The conditions for stability are; the growth rate in the annual number of births is constant or the age specific fertility rates (ASFR) are constant over time, age specific death rates are constant and the age specific rates of net migration are zero or constant over time.

2.3 Age structure and its dynamics.

The age structure represents the distribution of the population in each age group. It is affected by births, deaths, emigration and immigration. High rate of population growth produces a youthful population structure having a broad based pyramid age structure. Such a structure is characterized by high fertility, which leads to high demand for social amenities, education, health and food. The developing world has this kind of age structure and is focusing on steps to encourage stabilization. These steps include meeting the unmet demand for contraceptives, decreasing demand for large families and decreasing population momentum (the disparity between actual age distribution and the eventual stationary age distribution). For instance income tax deductions for dependent children and maternity and paternity leaves have been eliminate in Tanzania, Sri Lanka and Nepal (Muir, 2002).

By contrast, some of the slow (or negative) growth nations in the world like Sweden, Germany and Austria, are beginning to institute more policies in response to concern about diminishing populations. Some Scandinavian nations pay couples for each child they have. This is because of the columnar age structure (ageing population) where we have a larger proportion of old people than the young. The problems associated with old age have therefore to be addressed. Labor force supply becomes a problem that necessitates the employment of the elderly people to meet the shortfall.

Thus, the age structure can facilitate or impede development depending on whether the economy can adjust to the conditions generated by the transition (cf: Muir, 2002). Indeed, it is the concern of the government to make the population growth correspond to economic growth to achieve development. Governments therefore ought to be prepared for such eventualities. They therefore need both long term and middle term plans, which should be based on projections.

2.4 Background to projection methods.

Component method of population projection is the most widely used approach in the estimation of the future population in many countries including Kenya (CBS 1995, 2002; Wekesa, 1989; Rafig, 1992). One hindrance of this approach is that it does not give an indication to when the population can stabilize. Various assumptions on the growth rate are also made, that is high, medium and low rates, in anticipation of future changes. These entire assumptions give wide disparities .For instance UN's widest ranging projections for the size at which the human population will stabilize range between 3.6 and 27 billion people on earth. The difference between these two extremes involves only a difference of one child per woman (Muir, 2002). These projections do not indicate when the population would stabilize. Moreover, such wide disparities do not give a clear indication of the likely population size when stability is realized.

The exponential growth model is also used in the estimation of the future population given the base population and the growth rate but is limited to the total population only as the population of various age groups can not be estimated.

This study involves the use of matrix projection method. The method utilizes the prevailing rates of the base population, holding them constant over the projection period. No assumptions for the future growth rates are made. Thus the age structure that is produced at stability, unlike with the use of component method, does not depend on the current age structure but only on the fertility and mortality rates. The matrix method also gives an indication to when the population can stabilize and thus the corresponding age structure at stability can be obtained.

Matrix method allows forward projection as well as limited backward projection. It is economical in the use of space and simple in that from the second row onward it contains non-zero elements only in the sub-diagonal, which are the probabilities of passage from one age group to the next. The first row contains combination of probabilities of fertility at different ages and of survival for infants born in the projection interval. This projection matrix can also be condensed to obtain the stable matrix, which contains the dominant latent root (the ratio of population increase per year) from which we derive other demographic indicators among which are the natural rate of increase and the net reproductive rate. Such demographic indicators provide the basis for population policy formulations on manpower potential and utilization, education, environment, human settlements, health, agricultural activities and other development concerns.

Considering time and age as continuous and that growth is a continuous function of time, we obtain renewal equation, a fundamental integral equation for the stable population (Oyuke, 1982 and Makoteku 1985,1986) The renewal equation can be expressed as a matrix and be solved to obtain characteristic roots. The first characteristic root, denoted as λ_1, is the dominant latent root that is real and also positive. It is the only root that gives rise to a stable matrix or vector consisting of real and positive elements. It is this stable vector associated with the dominant root λ_1 which is ordinarily referred to as the stable age distribution appropriate to the given age specific rates of fertility and mortality (Leslie, 1945). The dominant root λ_1 is of great demographic interest. It represents the ratio of population increase per year and is the same as $\mathbf{e^r}$, where **r** is the Lotka's intrinsic rate of natural increase (Euler, 1960). From the root we can therefore obtain the rate of natural increase. Besides we can also obtain the net reproductive rate, denoted as **Ro**, from the approximate relation, $\mathbf{Ro} = \mathbf{e^{rT}}$,where **T** is the mean length of the generation.

Barnardelli (1941) first suggested the use of matrices in population projection. He noted from the sizes of Burmese birth cohorts that birth peaks occurred at intervals of a generation and that these might carry important economic and social implications, a question examined later by Richard Easterlin in the year 1966 (D. Smith and N. Keyfitz, 1977). From a projection matrix formed by holding fertility and mortality constant, Barnardelli isolated the characteristic roots of the net maternity function for the discrete case, identifying the dominant root as the intrinsic growth rate with the population and relating the other roots to oscillations in the birth rate.

Leslie (1945) in a definitive article developed the use of matrices fully. He used the earlier theory developed by Lotka. Keyfitz (1968) extended the work of Leslie in an interesting fashion. He made the projection matrix very simple. For the second row onward, it contains non-zero elements only in the sub-diagonal, which are the probabilities of passage from one age group to the next. The first row contains combinations of probabilities of fertility at different ages and of survival for infants born in the projection interval.

Tabah (1968) also showed how matrices might be applied to migration and labor force projections as well as to the overall population change. Later, Grevile and Keyfitz (1974) developed a generalized Leslie matrix to permit limited backward projection. This study utilizes the simplified work on matrices done by Nathan Keyfitz (1968).

Many countries including Kenya have done projection of their populations. CBS (2002) projected the population of Kenya to the year 2020. In these projections it was assumed that total fertility will not go below 3 births per women. With TFR of 3 and mortality stabilized at the level reached in 2020 , the population would ultimately settle into a steady rate of growth of rather less than 1% per annum (not specific of which rate). Net reproduction rate (the index of replacement or the expected number of female babies that will be born to a female baby who throughout her life will be subject to current age specific mortality and fertility rates) will not fall below unity until the period 2015-2020. The population would continue to grow until the middle of the century when it would reach a total of about 44 millions. Thereafter it would start to decline slowly (the point at stability is not told neither is the age structure then) (CBS, 2002).

Kocher (1979) projected the population of Tanzania using the component method that gave a wide margin of the population. Using the low rate of growth, the population was to be 70 million, medium rate 150 million, while 250 million with the high rate by the year 2050.

In 1990, India's population was 850 million persons. If total fertility rate in India dropped in 1990 to 2.4 and stayed there with death rates constant, the population of India would continue to increase for about 100 years, eventually stabilizing at about 2 billion people, or as many people as there were on earth in 1930 (Muir, 2002). According to CBS (2002) -Analytical report on population projection, Kenya's population growth rate at the national level is expected to decrease from around 2.2% per annum in 2001 to 1.7% in 2020.This will translate into a reduction of the population of Kenya from 30,208,365 in mid-2000 to 43,113,069 by 2020.

2.5 Summary of the literature review.

A stable population grows at a constant rate and it has a constant age structure. The knowledge of this age structure is important for the formulation of feasible population policies .To know such a population; projection of the current population has to be done. Component method of population projection is widely used in the estimation of the future population in many countries including Kenya. For instance UN's widest ranging projections for the size at which the human population will stabilize range between 3.6 and 27 billion people on earth. The difference between these two extremes involves only a difference of one child per woman (Muir, 2002). The preferred method of population projection in this study is the matrix projection method, which has also been widely used in demography (Barnardelli, 1941; Leslie, 1945; Euler, 1960; Keyfitz, 1968, 1974 and 1978). Keyfitz made the projection matrix very simple. For the second row onward, it contains non-zero elements only in the sub-diagonal, which are the probabilities of passage from one age group to the next. The first row contains combinations of probabilities of fertility at different ages and of survival for infants born in the projection interval.

CBS (2002) has projected the population of Kenya to the year 2020 with the assumption that total fertility will not go below 3 births per women. With TFR of 3 and mortality stabilized at the level reached in 2020, the population would ultimately settle into a steady rate of growth of rather less than 1% per annum and net reproduction rate will not fall below unity until the period 2015-2020 (not specific of which rate). The population would continue to grow until the middle of the century when it would reach a total of about 44 millions and thereafter decline slowly (the point at stability is not told neither is the age structure then). These generalizations by the CBS are resolved in this study.

CHAPTER THREE: DATA AND METHODS

3.1 Data source

The data used in this study was obtained from the 1999 Kenya Population Census, undertaken by the Central Bureau of Statistics (CBS) on the night of 24/25 August 1999. This Population and Housing Census was found to suffer a 2.77% under-coverage error and a high concentration of age misplacement around digits 0 and 5 and ages 20,30,40,50 and 60. However, the overall quality of reporting was found to be satisfactory. Due to these errors both of coverage and content, correction was necessary before use. CBS used a number of techniques to smoothen and adjust the reported age and sex data for the under coverage, age misstatement and digit preference. Principal among the techniques were a blend of stable population models, Population Analysis spreadsheets (PAS) and Basepop spreadsheet both developed by the United States Bureau of the Census. The adjusted and smoothed population of Kenya for 1999 was raised to 29,453,024 from 28,662,239.

For projection purposes, the corrected and graduated 1999 age –sex distribution was up-dated from the census date (25 August 1999) to mid-year 2000 using the Movepop spreadsheet developed by the US Bureau of Census. This is contained in the Analytical Report on Population projection. It is this up-dated, smoothed and adjusted population to mid –2000 that was used also in this study .The other set of data obtained were the L_x values and the ASFRs from the same analytical Report.

3.2 Method of analysis.

The analysis was done in two parts. Part one dealt with population projection that involved obtaining the projection matrix **L** (17×17) and projecting the population using the matrix **L**. Part two involved condensation of the matrix that involved extracting the matrix **M** (9×9) from **L** and condensing it to $\underline{\mathbf{M}}$ (3×3), taking the matrix $\underline{\mathbf{M}}$ to powers until it stabilized and obtaining the stable matrix **Z**. The characteristic root λ_1 was obtained and used to obtain the rate of natural increase, **r** and the net reproductive rate $\mathbf{R_0}$ Matlab and Excel computer packages were used extensively in the analysis.

3.2.1 Population projection

In population projection we are interested in answering the question, "Given the current population, what could be the future population?" The assumptions usually made are that the population is closed to migration; mortality and fertility rates are constant. Let ${}_nK_x^{(t)}$ be the population at time t whose ages are between x and x + n where the age interval n is taken as 5. Among those alive at t = 0 survivors to t = 1 are calculated as

$$\left.\begin{array}{l} (L_5/L_0)K_0^{(0)} = K_5^{(1)}, \\ (L_{10}/L_5)K_5^{(0)} = K_{10}^{(1)}, \\ \quad . \\ \quad . \\ \quad . \\ (L_{80+}/L_{75})K_{75}^{(0)} = K_{80+}^{(1)} \end{array}\right\} \qquad (1)$$

The typical age interval is from x at last birthday to x + 4, where x is a multiple of 5.

Equation **(1)** may be written as

$$(L_{x+5}/L_x)\, K_x^{(0)} = K_{x+5}^{(1)} \ , \qquad \textbf{(2)}$$

$x = 0, 5, \ldots\ldots\ldots\ldots \omega-5,$

ω being the maximum possible age taken as a multiple of 5.

Evidently the same operation of multiplying by an expected proportion surviving will on the same assumption give the expected number alive 10 years after the starting date as

$$(L_{x+10}/L_{x+5})\, K_{x+5}^{(1)} = (L_{x+10}/L_x)\, K_x^{(0)} = K_{x+10}^{(2)},$$

and similarly for later points of time.

The above **(2)** projects the populations already alive at the time zero, and to it must be added an allowance for births subsequent to that date. The age specific birth rates are obtained by observing the number of births to mothers x to x + 4 years of age at last birthday and dividing this by the average number of women in the same age group over the period of observation.

To follow the female population, the number of births of girl babies is required and it is assumed that the female fraction is the same for all ages of the mother .The female fraction is the ratio of female births to total births. This ratio is multiplied by the births in each age group of the mother to obtain the female birth in each age group. To obtain the age specific female birth rate F_x we divide the female births in each age group by the number of mothers in each age group.

The ratio F_x is multiplied by the arithmetic mean of the initial populations of ages x to x + 4 taken from **(1)**,

$$(K_x^{(0)} + K_x^{(1)})/2 = \tfrac{1}{2}(K_x^{(0)} + (L_x/L_{x-5})\, K_{x-5}^{(0)}) \qquad \textbf{(3)}$$

and since this number is exposed for 5 years, we multiply also by 5.

The women aged x to x + 4 together with those x + 5 to x + 9 at last birthday will make a contribution to the number of births during the 5 year time period from 0 to 1 of

$$5/2\{K_x^{(0)} + K_x^{(1)}\}F_x + 5/2\{K_{x+5}^{(0)} + K_{x+5}^{(1)}\}F_{x+5} + \ldots \qquad \textbf{(4)}$$

Adding through all ages and rearranging gives

$$\frac{5}{2}\sum_{\alpha-5}^{\beta-5}(F_x + (L_{x+5}/L_x)\, F_{x+5})\, K_x^{(0)}), \qquad \textbf{(5)}$$

where α is the youngest age of childbearing and β the oldest, both to be multiples of 5.

The last step is to survive the births in the five-year interval. The proportion of survivors among children born throughout the interval is,

$${}_5L_0/5l_0 \qquad \textbf{(6)}$$

Multiplying **(5)** and **(6)** gives $\mathbf{K_O}^{(1)}$, which is the term, needed to complete the population projection **(1)**. The relation between the population at time t + 1 and that at time t (where t is in units of 5 years) is a set of linear, first-order, homogeneous differential equations with constant coefficients given as:

$$
\left.
\begin{aligned}
& L_0/2l_0\left[\{K_{15}{}^{(t)} + K_{15}{}^{(t+1)}\} F_{15} + \{K_{20}{}^{(t)} + K_{20}{}^{(t+1)}\} F_{20} + \right. \\
& \qquad \left. \ldots + \{K_{45}{}^{(t)} + K_{45}{}^{(t+1)}\} F_{45} = K_0{}^{(t+1)}\right], \\
& \left(L_5/L_0\right) K_0{}^{(t)} = K_5{}^{(t+1)}, \\
& \quad . \\
& \quad . \\
& \quad . \\
& \left(L_{80+}/L_{75}\right) K_{75}{}^{(t)} = K_{80+}{}^{(t+1)},
\end{aligned}
\right\} \qquad (7)
$$

where the childbearing span is taken as 15 to 49.

The entire set above can be compactly written as:

$$\mathbf{L}\ \{\mathbf{K}^{(t)}\} = \{\mathbf{K}^{(t+1)}\}, \qquad \mathbf{(8)}$$

where $\{\mathbf{K}^{(t)}\}$ is the vertical vector of the age distribution at time t,

$$\mathbf{K}^{(t)} = \begin{Bmatrix} K_0{}^{(t)} \\ K_5{}^{(t)} \\ . \\ . \\ . \\ K_{80}{}^{(t)} \end{Bmatrix},$$

and **L** is the matrix of the coefficients of $K_x^{(t)}$ in **(7)** after the $K_x^{(t+1)}$ are eliminated on the left:

$$\mathbf{L} = \begin{pmatrix} 0 & 0 & L_0/2l_0\left((L_{15}/L_{10})\,F15\right) & L_0/2l_0\left(F_{15} + (L_{15}/L_{10})F_{20}\right) & \ldots 0 & 0 \\ L_5/L_0 & 0 & 0 & 0 & \ldots 0 & 0 \\ 0 & L_{10}/L_5 & 0 & 0 & \ldots 0 & 0 \\ \cdot & & & & & \cdot \\ \cdot & & & & & \cdot \\ \cdot & & & & & \cdot \\ 0 & 0 & 0 & 0 & \ldots L_{80+}/L_{75} & 0 \end{pmatrix} \quad \textbf{(9)}$$

Two approaches to solving equation **(8)** are possible. The first is to treat the equation as though it were an equation in scalars, and solve, without any deeper analysis, by

$$\mathbf{L\{K^{(0)}\} = \{K^{(1)}\}, L\{K^{(1}\} = \{K^{(2)}\},} \quad \textbf{(10)}$$

this can be re-written as

$$\mathbf{\{K^{(t)}\} = L^{t}\,\{K^{(0)}\}} \quad \textbf{(11)}$$

to facilitate the study of the effects of the pattern of fertility and mortality contained in **L** and $\mathbf{L}^t$, in separation from the initial age distribution $\mathbf{K}^{(0)}$.

The other approach is to analyze the matrix of the coefficients in terms of its latent roots. Matrix **L** and its powers may be written as four sub matrices by a split at a point which corresponds to the highest age of reproduction β ,

$$L = \begin{bmatrix} M & O \\ A & B \end{bmatrix}, \; L^2 = \begin{bmatrix} M^2 & 0 \\ AM + BA & B \end{bmatrix} \quad L^t = \begin{bmatrix} M^t & 0 \\ A_t & B^t \end{bmatrix},$$

where $\mathbf{A_t}$ is a function of **A, B,** and **M** whose explicit form is not required. The important feature of the partition is that the upper right –hand sub matrix is zero, and it remains zero at all positive integral power of **L**. Splitting vector **{K}** at the highest age of reproduction, say as

$$\{K\} = \begin{bmatrix} K \\ D \end{bmatrix},$$

then $\{\mathbf{K}^{(t)}\}$ becomes,

$$\{K^t\} = L^t\{K^{(0)}\} = \begin{bmatrix} M^t & 0 \\ A_t & B^t \end{bmatrix} \begin{bmatrix} K \\ D \end{bmatrix}$$

$$= \begin{Bmatrix} M^tK^{(0)} \\ A_tK^{(0)} + B^tD^{(0)} \end{Bmatrix} = \begin{bmatrix} K^{(t)} \\ D^{(t)} \end{bmatrix}.$$

from which it is evident that the A, B and the D, referring to the ages beyond reproduction, that is beyond β, never affect the ages younger than β. Our interest is on the matrix $\mathbf{M^t}$ and the vector

$\{\mathbf{K}^{(t)}\}$ covering the interval from birth to the end of the fertile ages only, rather than $\mathbf{L}^t$ and $\{\mathbf{K}^{(t)}\}$, which deal with the whole of life.

3.2.2 Condensation of the matrix.

This condensation involves the deriving of a usable 3×3 matrix. This matrix helps us to analyze the stable population to obtain the dominant root, which in turn helps us to get the rate of natural increase and the net reproductive rate. We start with **M**, compiled in nine five –year age groups upto ages 45 and cube it to obtain $\mathbf{M}^3$. In parallel to the symbols

$$\mathbf{M}\,\{\mathbf{K}^{(0)}\} = \{\mathbf{K}^{(1)}\},$$

we write the 3×3 matrix as

$$\underline{\mathbf{M}}\,\{\underline{\mathbf{K}}^{(0)}\} = \{\underline{\mathbf{K}}^{(1)}\}. \qquad \textbf{(12)}$$

The age groups are condensed into 15-year age groups and 15-year time interval where the j^{th} element of the i^{th} row of $\underline{\mathbf{M}}$ **is** $\underline{m}_{ij}$, and the i^{th} element of the $\{\underline{K}^{(0)}\}$is $k_i^{(0)}$, i =1,2,3; j =1,2,3, so that explicitly **(12)** is

$$\begin{pmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{pmatrix} \begin{Bmatrix} k_1^{(0)} \\ k_2^{(0)} \\ k_3^{(0)} \end{Bmatrix} = \begin{Bmatrix} k_1^{(1)} \\ k_2^{(1)} \\ k_3^{(1)} \end{Bmatrix}.$$

The m_{ij} from the elements of $\mathbf{M}^3$ which we call $m_{ij}^{(3)}$ and the k_i,=1,2….,9, j = 1,2,….,9, must meet two conditions. The first is that as nearly as possible each 15-year age group in the population as projected once through 15 years by the small matrix $\underline{\mathbf{M}}$ be equal to the sum of corresponding three ages in the population as projected three times (each through 5 years) by the large matrix **M**.

If $\{K^{(3)}\} = M^3 \{K^{(0)}\}$ is to be equivalent to $\{\underline{K}^{(1)}\} = \underline{M}\{\underline{K}^{(0)}\}$, then

$$\underline{k}_1^{(1)} = k_1^{(3)} + k_2^{(3)} + k_3^{(3)},$$

since both sides stand for the population less than 15 years of age, at 15 calendar years after the zero point. Similarly for $\underline{k}_2^{(1)}$ and $\underline{k}_3^{(1)}$. The second condition is that the cohorts each move into the following 15 year each group over the 15 year period of projection by the small matrix. We make each element in the small matrix $\underline{\mathbf{M}}$ depend only on the corresponding square in the partition of $\mathbf{M}^3$; m_{11} will depend only on the upper left 3×3 of $\mathbf{M}^3$ for example , and will in no way be affected by the birth and death in the range out-side of that $k_1 + k_2 + k_3$. The equation representing the two conditions for the upper left of the nine sub matrices into which **M** is divided is

$$\left.\begin{aligned} & m_{11}^{(3)}k_1 + m_{12}^{(3)}k_2 + m_{13}^{(3)}k_3 \\ & + m_{21}^{(3)}k_1 + m_{22}^{(3)}k_2 + m_{23}^{(3)}k_3 \\ & + m_{31}^{(3)}k_1 + m_{32}^{(3)}k_2 + m_{33}^{(3)}k_3 \\ & = \underline{m}_{11}(k_1 + k_2 + k_3), \end{aligned}\right\} \qquad \textbf{(13)}$$

and on solving for m_{11} we have

$$\underline{m}_{11} = \frac{k_1\sum_{i=1}^{3} m_{i1} + k_2\sum_{i=1}^{3} m_{i2} + k_3\sum_{i=1}^{3} m_{i3}}{k_1 + k_2 + k_3}.$$

A similar argument applies to the remainder of the $\underline{m}_{ij}$, i = 1,2,3 j = 1,2,3.The construction of the 3×3 matrix $\underline{\mathbf{M}}$ now requires only a decision on the k_1 , k_2 and k_3 These are chosen from the age distribution, which would be reached by the continued operation of **M** to give the stable population in which the ks' are only available to within a multiplicative constant. They depend in no way on the initial age distribution though they are calculated as

$$\{\mathbf{K}_t\} = \mathbf{M}^t \{\mathbf{K}^{(0)}\}.$$

The matrix $\underline{\mathbf{M}}$ is of such character that when taken to powers it stabilizes. The second power corresponds to the projection through 30 years, the third through 45 years, and so forth. This is done until the power of $\underline{\mathbf{M}}$ that is approximately stable is obtained. Its rows should be proportional to one another, and its columns likewise, and also in the sense that each higher power is proportional, element by element to this matrix. The common value of the ratio in the limit is denoted by λ_1, which is the principal latent or characteristic root. The dominant root λ_1 is of great demographic interest. It represents the ratio of population increase per year and is the same as $\mathbf{e}^r$, where $\mathbf{r}$ is the Lotka's intrinsic rate of natural increase (Euler, 1960). From this root we can therefore obtain the rate of natural increase. Besides we can also obtain the net reproductive rate, denoted as Ro, from the approximate relation, $\mathbf{Ro} = \mathbf{e}^{r\mathbf{T}}$,where $\mathbf{T}$ is the mean length of the generation.

CHAPTER FOUR: POPULATION PROJECTION

4.1 Introduction

This chapter presents the results of the analysis. It explains how to obtain the projection matrix **L**, projecting the population using matrix **L**, condensing the projection matrix **L (17 x 17)** to **M** **(3 x 3)** and finally compares the results obtained with the prevailing related demographic indicators.

4.2 Obtaining the projection matrix L

The concepts behind the construction of the projection matrix **L** have already been discussed in the previous chapter. The required fertility and mortality rates are presented below.

Table 1: **Age specific female fertility rate, F_x.**

Age- Group	ASFR	F_x = FF*ASFR
15—19	0.1137	0.0560
20--24	0.2008	0.0989
25--29	0.1868	0.0920
30--34	0.1465	0.0722
35--39	0.1007	0.0496
40—44	0.0495	0.0244

Source: Computed from appendix 2.

The ASFR of age group 10 – 14 from appendix 2 have been added to those of age group 15 – 19 while the ASFR of age group 45 – 49 have been added to those of age group 40 – 44 in the above Table 1. The sex ratio at birth of the 1999 census was given as 1.03(CBS, 2002). The sex ratio is used in calculating the female fraction. Thus the female fraction (female births over the total births) abbreviated as FF = 100/203 = 0.4984. This has been multiplied by ASFR to obtain the F_x values. F_x values are the age specific fertility rates that correspond only to girl children being born.

The mortality values needed are the L_x values, which are extracted from appendix 3. Only the female L_x values are used since the females contribute to the increase in population through child bearing. Some adjustments to the values in appendix 3 are necessary and are as follows; ${}_5L_0 = 0.25l_0 + 2.65\,l_1 + 2.5\,l_5$ The other L_x values remain the same having been calculated as ${}_5L_x = 5/2(l_x + l_{x+5})$. Using the L_x values we obtain the Survival ratio, ${}_nSR_x = {}_nL_x/{}_nL_{x-5}$. The last age group considered was 80+ with $SR = T_{80+}/T_{75+}$. These values of the survival ratio constituted the diagonal values in the projection matrix **L**, given earlier as **(9)** .The values of the first row of the matrix **L** are obtained from the relation, $L_0/2l_0\,(F_{x-5}+ (L_x/L_{x-5})F_x)$, given earlier as **(7).** All these are summarized in the Table 2 below.

Table 2: **Diagonal and first row values of Matrix L**

AGE:	FEMALE			
	Diagonal value		First Row values	
	Lx	${}_nSR_{xF}$	F_x	$L_0/2l_0\,(F_{x-5}+(L_x/L_{x-5})F_x)$
0	4.9336			
5	4.4020	0.8922		
10	4.3398	0.9859		
15	4.3032	0.9916	0.0560	0.1370
20	4.2122	0.9789	0.0989	0.3770
25	4.0045	0.9507	0.0920	0.4598
30	3.7041	0.9250	0.0722	0.3917
35	3.4041	0.9190	0.0496	0.2905
40	3.1402	0.9225	0.0244	0.1779
45	2.9200	0.9299		
50	2.7172	0.9305		
55	2.4947	0.9181		
60	2.2609	0.9063		
65	2.0068	0.8876		
70	1.6928	0.8435		
75	1.2909	0.7626		
80+	0.8260	0.5124		

Source: Computed from Table 1 and appendix 3.

The above Table 2 values are presented in the projection matrix **L** given below. The first row values are the probabilities of fertility at different ages and of survival of infants born in the projection interval. These increase with age to age 29 after which they decrease. The peak reproductive age group is 25-29. It is worth noting that the survival ratios reduce drastically from reproductive age group15-19 to the end of reproductive age group 45 -49. The reproductive age group adversely affected by mortality is the age group 35-39, with a survival ratio of 0.919.The second most affected age group is the 30-34 with the survival ratio of 0.925.This is a strong indication of the effect of maternal mortality on the ageing mothers. The maternal mortality is higher in older mothers than in the younger ones as per the base population of 2000. On the overall the survival ratios decrease with age, which is the expected trend. However, the fluctuation noted in the reproductive age groups can only be attributed to maternal mortality. The other possibility worthy investigating is the effect of HIV/AIDS that contribute to high mortality in the reproductive age groups.

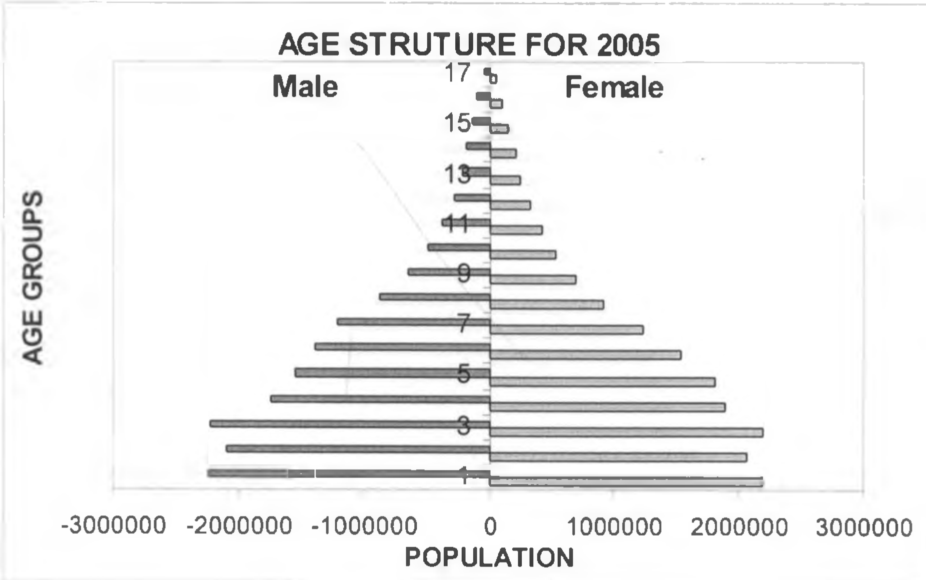
PROJECTION MATRIX L (17 X17)

$$
\begin{pmatrix}
0 & 0 & 0 & .1370 & .3770 & .4598 & .3917 & .2905 & .1779 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
.8922 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & .9859 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & .9919 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & .9789 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & .9507 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & .9250 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .9190 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .9225 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .9299 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .9305 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .9181 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .9063 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .8876 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .8435 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .7626 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & .5124 & 0
\end{pmatrix}
$$

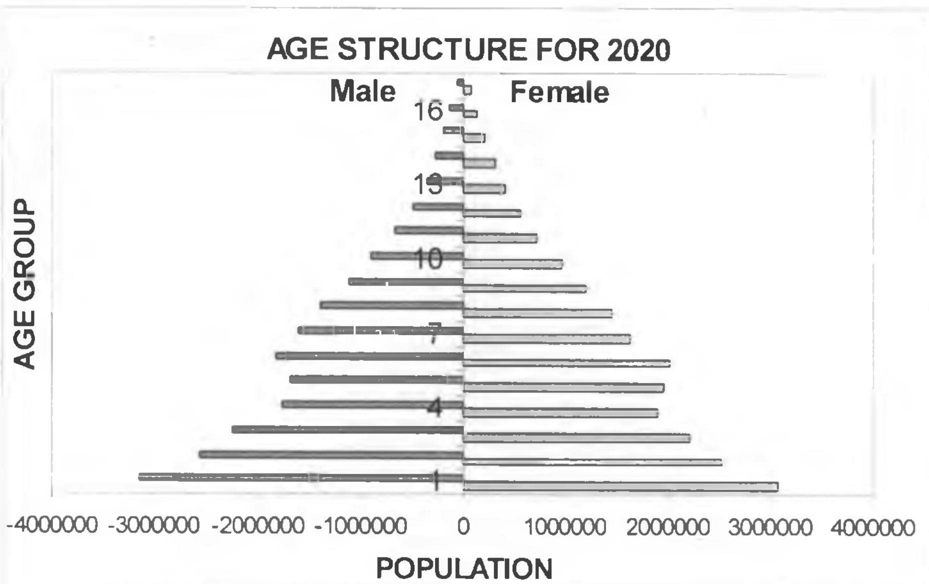
4.3 Projecting the population using the projection matrix L

The base population of 2000 in Appendix 1 is used in the projection together with the above-generated projection matrix **L.** The relation **(11)** described in chapter three is used here, where the matrix **L** is taken to powers with the help of the Matlab computer program and then pre-multiplied with the female base population to obtain the subsequent projected populations. The corresponding male population was obtained by multiplying the projected female population with the sex ratio calculated in Appendix 1 .The results have been presented in Appendix 4.

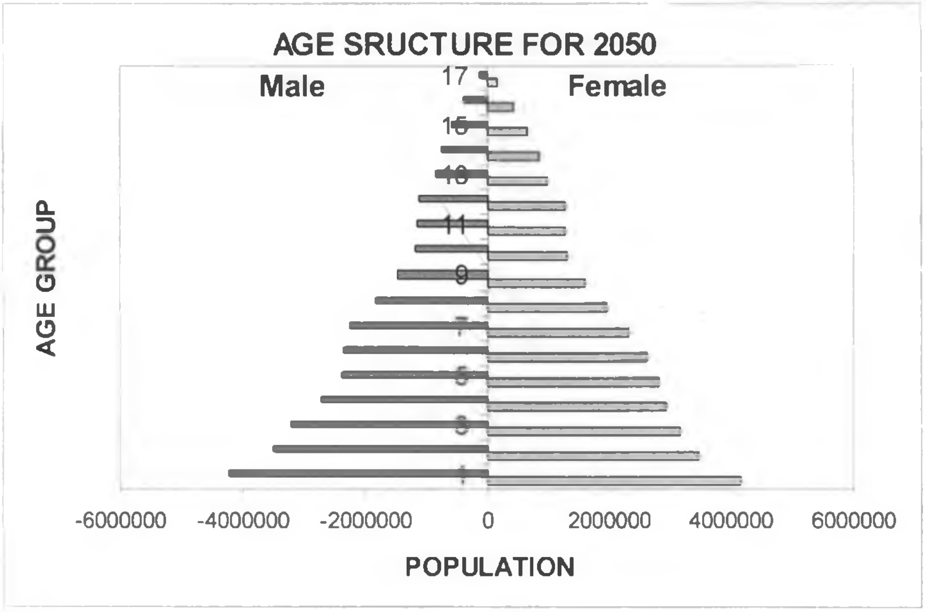
As indicated earlier the objective of projecting the population is to obtain the stable population structure for Kenya. To achieve this objective the population was projected to the year 2145. Respective age structures were done and the results show that the age structure was becoming stable as we approached year 2090. The age structure in the year 2090 is stable and this structure remains the same even to the year 2145. The age structures of the years 2005, 2020, 2050, 2090, 2120 and 2145 have been picked on and illustrated below to show the change in the age structures to stability and how the structure remains the same after stability. It is worthy noting that whereas the population increases in size the age structure does not change. This implies that if the current fertility and mortality rates in Kenya remain unchanged, the Kenyan population age structure will stabilize by the year 2090 with a youthful age structure.



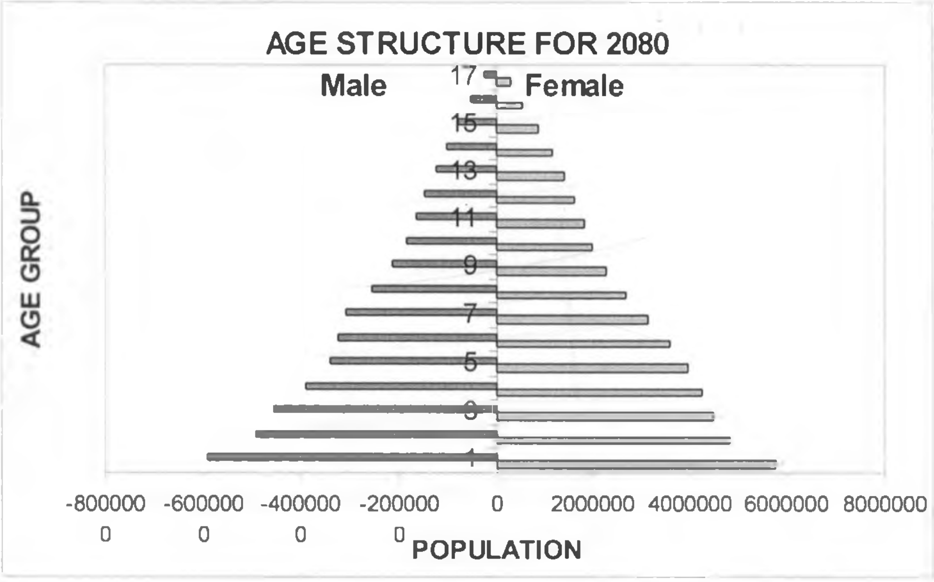
The age structure is not smooth. It shows a youthful population.



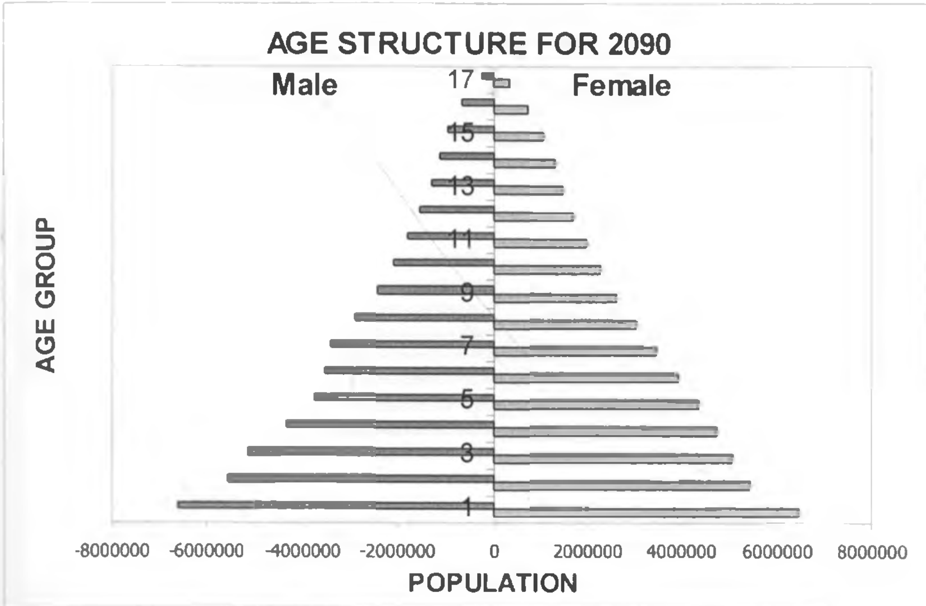
The age structure is not smooth. It shows a youthful population



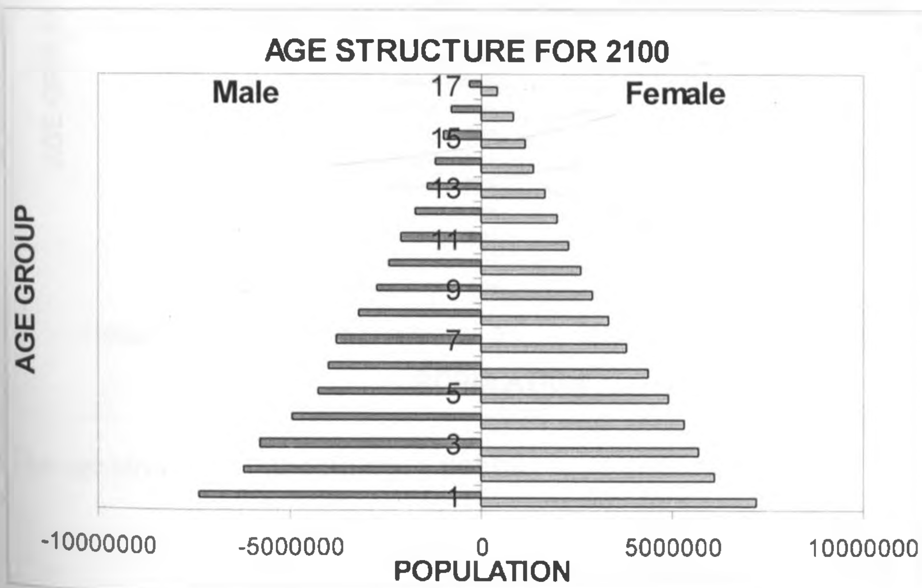
The age structure is becoming smooth. It shows a youthful population



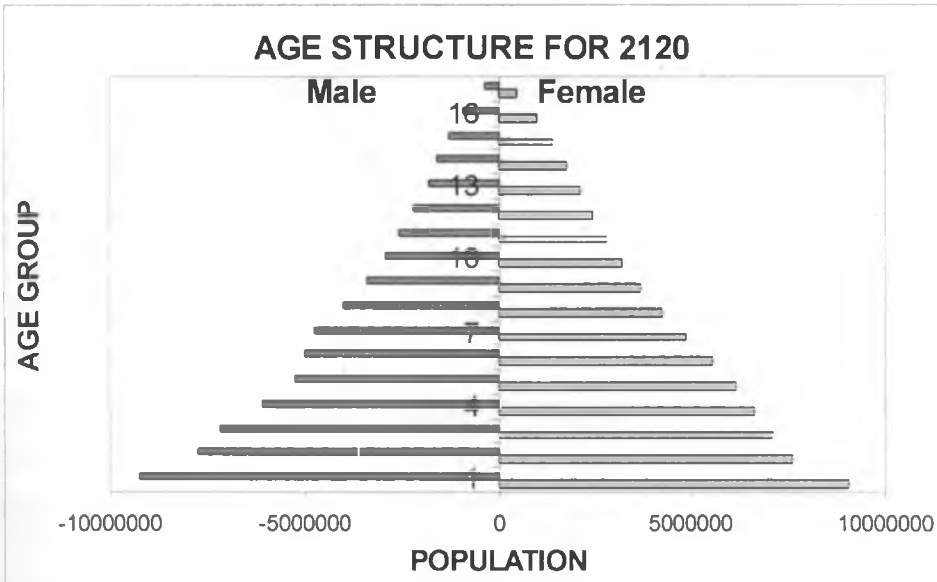
The age structure is almost smooth. It shows a youthful population



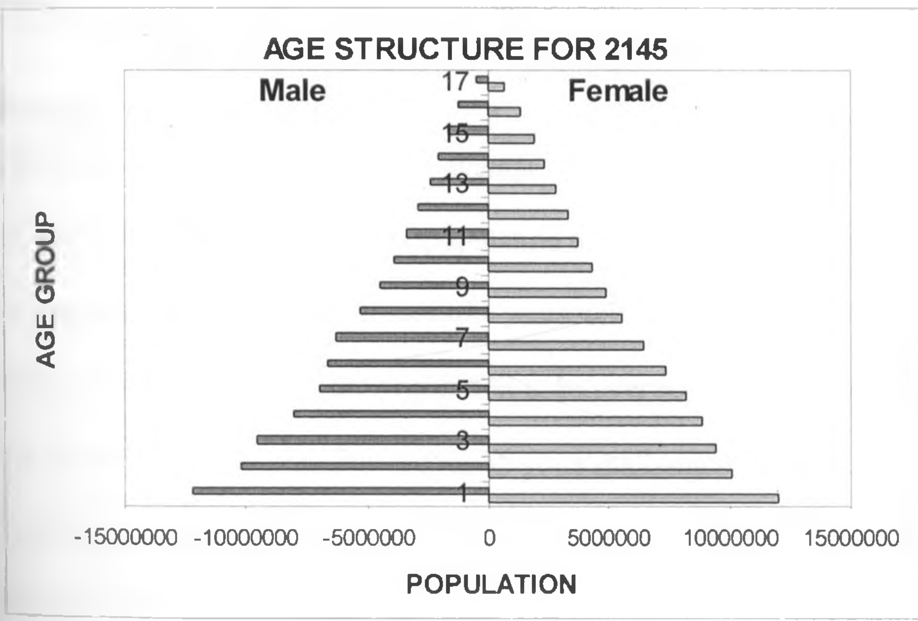
The age structure is smooth and youthful. This age structure and the preceding ones are the same. Thus, this is the stable age structure that the Kenyan population will acquire under the mortality and fertility rates of the base population of 2000.



The age structure is smooth and youthful.



The age structure is smooth and youthful.



The age structure is smooth and youthful.

Further analysis of the age structure of the projected population show that it will have a higher proportion of old people than the current population while those aged 15 years and less will reduce in number .The dependency ratio will also reduce though by a small percentage .The Table 3 below summarizes these observations in the selected years.

Table 3: Dependency ratio and Total population in selected years.

	2005	2020	2050	2080	2090	2100	2145
Dependency ratio	76	69.59	70.62	70.3	71.79	71.12	71.01
% of <15	40.14	37.72	35.01	35.05	35.19	35.11	35.11
% of 55+	6.38	7.69	13.19	12.77	12.78	12.65	12.72
% of 65+	3.04	3.32	6.38	6.23	6.6	6.46	6.42
Mean age of females	23.43	25.33	28.01	27.95	28.02	28.01	28.00
Total population	32406554	41836868	62198604	86983064	97584844	109049857	180664500

Source: Appendix 4 and 5

The dependency ratio decreases on average. In the year 2005 it will be 76% while at stability in the year 2090 it will be 71%. The population under 15 will also decrease from 40% to 35% over the same period. The population of 65+ years will increase over the period. In the year 2005 we expect to have only 3% of the population to be over 65 years. In the year 2090, the population will have 6.6% of the population over 65 years implying more than double of the current population. If we consider the over 55+years then we expect 12.78% of the population at stability from 6.38% expected next year. The total population would double by the year 2050 to be 62.2 millions from 30.2 millions of the year 2000 and by the time the population acquire a stable age structure in the year 2090, the population size will have tripled to 97.6 millions. Over the same period, the mean age of the female population will be 23.43 years, 25.33 years, 28.01 years, and 27.95 years 28.02 years, 28.01 years and 28.00 years respectively. This is a clear indication of the ageing population. These mean ages have been calculated and presented in appendix 5.

4.4Condensation of the projection matrix

The condensed matrix helps us to analyze the stable population by obtaining the dominant latent root, which in turn helps us to get the rate of natural increase and the net reproductive rate. The condensation of the projection matrix **L** involves the extraction of matrix **M** that consists of the first nine rows and columns of **L**. This matrix **M** is then cubed to obtain $\mathbf{M}^3$. The $\mathbf{M}^3$ and the k_i values obtained from the projected population of 2090 are used in the earlier equation **(13)** to obtain the condensed matrix $\underline{\mathbf{M}}$ (3 X3). The population of 2090 is used because it belongs to the stable population and also the projection matrix does not depend on the base population but only on the fertility and mortality rates. The matrix **M,** $\mathbf{M}^3$**,** k_i values of the year2090 and the resultant condensed matrix **M** are shown below.

MATRIX M (9 X 9)

$$\begin{pmatrix} 0 & 0 & 0 & 0.137 & 0.377 & 0.4598 & 0.3917 & 0.2905 & 0.1779 \\ 0.8922 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.9859 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.9916 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.9789 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.9507 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.925 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.919 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9225 & 0 \end{pmatrix}$$

MATRIX M^3

$$\begin{pmatrix} 0 & 0.1339 & 0.3659 & 0.4279 & 0.3445 & 0.2469 & 0.1508 & 0 & 0 \\ 0 & 0 & 0.1212 & 0.3293 & 0.39 & 0.3233 & 0.2382 & 0.1464 & 0 \\ 0 & 0 & 0 & 0.1205 & 0.3316 & 0.4044 & 0.3445 & 0.2555 & 0.1565 \\ 0.8722 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.957 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.9228 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.8608 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.8082 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.7842 & 0 & 0 & 0 \end{pmatrix}$$

	YEAR2090
	K18
k_1	6,488,000
k_2	5,481,000
k_3	5,093,000
k_4	4,744,600
k_5	4,374,300
k_6	3,945,600
k_7	3,485,300
k_8	3,056,700
k_9	2,655,400

Source: Appendix 4

M **(3x3)** =

$$\begin{bmatrix} 0.1884 & 0.9700 & 0.4567 \\ 0.9145 & 0 & 0 \\ 0 & 0.8201 & 0 \end{bmatrix}$$

Matrix **M** is of such characteristic that it stabilizes when taken to powers. The second power corresponds to projection through 30 years, the third through 45 years and so forth.

Table 4: Powers of matrix M

$$M^2 = \begin{bmatrix} 0.9226 & 0.5573 & 0.0860 \\ 0.1723 & 0.8871 & 0.4177 \\ 0.7500 & 0 & 0 \end{bmatrix} \qquad M^4 = \begin{bmatrix} 1.0117 & 1.0085 & 0.3121 \\ 0.6250 & 0.8829 & 0.3853 \\ 0.6919 & 0.4180 & 0.0645 \end{bmatrix}$$

$$M^8 = \begin{bmatrix} 1.8697 & 2.0411 & 0.7245 \\ 1.4507 & 1.5709 & 0.5601 \\ 1.0058 & 1.0938 & 0.3812 \end{bmatrix} \qquad M^{16} = \begin{bmatrix} 7.1857 & 7.815 & 2.7741 \\ 5.548 & 6.0414 & 2.1445 \\ 3.8508 & 4.1881 & 1.4867 \end{bmatrix}$$

$$M^{17} = \begin{bmatrix} 8.5006 & 9.2452 & 3.2817 \\ 6.5713 & 7.1468 & 2.5369 \\ 4.5555 & 4.9545 & 1.7587 \end{bmatrix} \qquad M^{18} = \begin{bmatrix} 10.0562 & 10.9369 & 3.8822 \\ 7.7738 & 8.4547 & 3.0011 \\ 5.3892 & 5.8611 & 2.0805 \end{bmatrix}$$

$$M^{19} = \begin{bmatrix} 1.8964 & 12.9383 & 4.5927 \\ 9.1964 & 10.0018 & 3.5503 \\ 6.3753 & 6.9337 & 2.4612 \end{bmatrix} \qquad M^{20} = \begin{bmatrix} 14.0734 & 15.306 & 5.4331 \\ 10.8793 & 11.8321 & 4.2 \\ 7.542 & 8.2025 & 2.9116 \end{bmatrix}$$

$$M^{33} = \begin{bmatrix} 125.0753 & 136.0297 & 48.2859 \\ 96.6881 & 105.1562 & 37.3269 \\ 67.0281 & 72.8986 & 25.8765 \end{bmatrix} \qquad M^{32} = \begin{bmatrix} 105.7278 & 114.9877 & 40.8167 \\ 81.7317 & 88.8899 & 31.5529 \\ 56.6598 & 61.6221 & 21.8737 \end{bmatrix}$$

Table 5: The dominant latent root

M^{17}/M^{16} $\begin{bmatrix} 1.1830 & 1.1830 & 1.1830 \\ 1.1844 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \end{bmatrix}$ M^{18}/M^{17} $\begin{bmatrix} 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \end{bmatrix}$

M^{19}/M^{18} $\begin{bmatrix} 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \end{bmatrix}$ M^{33}/M^{32} $\begin{bmatrix} 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \end{bmatrix}$

M^{20}/M^{19} $\begin{bmatrix} 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \\ 1.1830 & 1.1830 & 1.1830 \end{bmatrix}$

From the above results, it is established that the stable matrix is obtained when $\underline{\mathbf{M}}$ is taken to power 18. It is proved by its division with $\underline{\mathbf{M}}$ taken to the power of 17 .The result of the division shows a constant quotient of 1.183 which is the dominant latent root or the characteristic root. To show that the dominant root does not change even when we get higher powers of matrix $\underline{\mathbf{M}}$, $\underline{\mathbf{M}}$ was taken to power 32 and 33 and their quotient obtained as shown above. The quotient remained the same at 1.183. Table 5 above shows these results. To obtain the first stable matrix, which is often called the spectral component denoted as $\mathbf{Z_1}$, we divide $\underline{\mathbf{M}}^{18}$ by the characteristic root λ_1^{18}. Thus, $\mathbf{Z_1} = \underline{\mathbf{M}}^{18} / \lambda_1^{18}$ =

$$\begin{bmatrix} 0.4883 & 0.5311 & 0.1885 \\ 0.3775 & 0.4106 & 0.1457 \\ 0.2617 & 0.2846 & 0.1010 \end{bmatrix}$$

Where λ_1^{18} = 1.183^18 = 20.59.

Since the dominant root represents the ratio of population increase per year, it means that the ratio at which the Kenyan population will be increasing when it has acquired the stable age structure will be 1.183 per year. The intrinsic rate of natural increase in this stable age structure will be 0.0022 or 0.22%. This is obtained from the relationship **r** = ln (λ_1)/ (15*5). The net reproductive rate **Ro**, is obtained from the approximate relation, **Ro** = $\mathbf{e}^{rT}$,where T is the mean length of the generation of the female population of the year 2090 at which the Kenyan population will have acquired the stable age structure.

The characteristic root or the dominant root, λ_1 = 1.183. With λ_1 we calculate the rate of natural increase **r** = ln (λ_1)/ (15*5) = 0.0022=0.22% and the net reproductive rate **Ro** = $\mathbf{e}^{rT}$ = 1.0636. When **Ro** = 1 then the population is stationary. When more than 1, the population biologically speaking is more than holding its own, although the actual number of the heads to be counted may be temporally decreasing. When less than 1 then the population can not be able to replace itself. This is what is being experienced in countries like Sweden and Singapore. Since the Kenyan **Ro** value is 1.0636, almost near unity yet the fertility level used are comparatively high then it means that as efforts to reduce fertility levels are made, the Kenyan population might stabilize at below replacement level just as Singapore. The rate of natural increase, **r** of 0.22% per annum is also low confirming the possibility of the population falling below replenishment level. In 1965 United States had λ_1 = 1.2093 and **r** = 0.01267(1.27%) while Hungary had λ_1 = 0.8993 and **r** = -0.00708(-0.71%) (Keyfitz, 1968).

4.5 Comparison of the results.

CBS (2002) has projected the population of Kenya to the year 2020 with the assumption that total fertility will not drop to below 3 births per women. With TFR of 3 and mortality stabilizing at the level reached in 2020, the population would ultimately settle into a steady rate of growth of rather less than 1% per annum and net reproduction rate will not fall below unity until the period 2015-2020 (not specific of which rate). The population would continue to grow until the middle of the century when it would reach a total of about 44 millions and thereafter decline slowly (the point at stability is not told neither is the age structure then). The population growth rate at the national level is expected to decrease from around 2.2% per annum in 2001 to 1.7% in 2020.This will translate into a reduction of the population of Kenya from 30,208,365 in mid-2000 to 43,113,069 by 2020

This study show that the population of Kenya would acquire a stable population structure by the year 2090.The age structure would be youthful with a broad based pyramid shape. The intrinsic growth rate of the stable population will be 0.22% per annum. This is in agreement with the CBS prediction of less than 1%. The net reproduction rate for Kenya will not at all fall below unity. The net reproduction rate of the population will be 1.0636 as per the findings of this study. The findings show that by the middle of the century, the population of Kenya will be 62.2 million. After that it will continue to grow but then by the year 2090 acquire a stable age structure. However, the population size will still increase as shown in the projections in appendix 4. The population according to the projections is to be 32.4 millions, 41.8 millions, 62.2 millions, 97.6 millions, 109 millions and 180.6 millions in the years 2005, 2020, 2050, 2090, 2100 and 2145 respectively under the current fertility and mortality rates. Over the same period, the mean age of the female population will be 23.43 years, 25.33 years, 28.01 years, and 27.95 years 28.02 years, 28.01 years and 28.00 years respectively. This is a clear indication of the ageing population .The mean age of females in the base population of 2000 is only 22.62 years while in 2090, at the time the population acquires the stable age structure it will be 28.02 years showing an increase of 5.4 years.

CHAPTER FIVE: FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the research findings, makes conclusions and recommendations based on the research findings.

5.2Summary of the findings and conclusions

The general objective of the study was to project the population of Kenya to stability. The study specifically looked at obtaining the projection matrix for Kenya, estimating the stable age structure for Kenya and comparing the population size, rate of natural increase and the net reproductive rate of the stable population with the current reported and related demographic indicators.

The projection matrix for Kenya was obtained. It contains non-zero elements only in the sub-diagonal, which are the probabilities of passage from one age group to the next. The first row contains combinations of probabilities of fertility at different ages and of survival for infants born in the projection interval. This matrix was then used to project the Kenyan population until it stabilized by the year 2090 with a youthful age structure. According to the projections the population size is to be 32.4 millions, 41.8 millions, 62.2 millions, 97.6 millions, 109 millions and 180.6 millions in the years 2005, 2020, 2050, 2090, 2100 and 2145 respectively. This depicts a rapid population increase under the current fertility and mortality levels. If efforts are made to reduce the fertility levels then the population increase will be slowed down. The population will also be ageing over time as shown by the mean age of the female populations of 23.43 years, 25.33 years, 28.01 years, and 27.95 years 28.02 years, 28.01 years and 28.00 years in the year 2005, 2020, 2050, 2080, 2090, 2100 and 2145 respectively.

Further analysis of the projection matrix by condensation revealed that the dominant latent root, which represents the ratio of population increase per annum is 1.183.This gave the intrinsic natural rate of growth of 0.22% per annum and the net reproductive rate of 1.0636.

5.3 Conclusions.

The study show that the population of Kenya will stabilize by the year 2090 with a broad based pyramid youthful age structure. Though the population age structure will be stable, the population size will continue increasing at the intrinsic growth rate of 0.22% per annum. The net reproductive rate of 1.0636 at stability means that the current population will be able to replenish itself since it is more than unity. The Kenyan population will become older as shown by the difference in the mean age of the females of 5.4 years in the year 2000 and 2090 at the time of stability.

5.4 Recommendations for Policy.

The study show that the population size will continue to increase rapidly over time under the current fertility and mortality rates. The government should therefore set policies that address the expansion of the existing facilities and proper utilization of the available resources. In particular policies that address investment in consumer projects like education, food security, health and housing should be reviewed to accommodate the increasing numbers. Policies should also be set up and reinforced to ensure that the economic growth rate is increasing in direct proportion to the population growth rate in order to achieve national development. The ageing population of Kenya necessitates the government to consider reviewing the policy on retirement age of the civil servants from the current 55 years to 60 years to incorporate the difference brought about by the ageing population.

5.5 Recommendations for further research

An agreement between the stable and observed ages testifies to the fixity of the preceding regime of fertility and mortality while a difference between the stable and observed shows that the regime has been changing or else migration has taken place. This in turn helps in the calculation of the index of dissimilarity – the departure of the stable population from the observed age distributions. We therefore recommend further research, using the same method say in intervals of 10 years to see the effects of the changing rates on the projected population and age structure at stability. Simulation can also be done to establish the effects of varying fertility and mortality rates on the population structure.

In this study we have only obtained the first characteristic root. We recommend the extension of this study to obtain other roots and ascertain their demographic implications .This is possible through matrix algebra of the projection process which involves obtaining homogeneous linear equations.

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APPENDIX 1:1999 POPULATION CENSUS – CORRECTED AND MID- YEAR POPULATION FOR 2000.

SMOOTHED AND ADJUSTED POPULATION				BASE POPULATION JULY, 2000			
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	SEX RATIO
ALL AGES	14342209	15110815	29453024	14704286	15504079	30208365	
Under 1	509531	512802	1022333				
0—4	2342576	2366559	4709135	2351555	2314288	4665843	1.0161
5—9	1987900	2028015	4015915	2261094	2233882	4494976	1.0122
10—14	1995510	2034447	4029957	1932516	1916130	3848646	1.0086
15—19	1740730	1820619	3561349	1691262	1850118	3541380	0.9141
20—24	1379948	1560951	2940899	1386113	1624193	3010306	0.8534
25—29	1124732	1280910	2405642	1201737	1339007	2540744	0.8975
30—34	885768	940088	1825856	971438	997195	1968633	0.9742
35—39	703401	728140	1431541	722167	762217	1484384	0.9475
40—44	534186	551737	1085923	531011	581121	1112132	0.9138
45—49	418546	431630	850176	411606	452359	863965	0.9099
50—54	322763	334748	657511	318011	351610	669621	0.9044
55—59	254342	270412	524754	250040	281137	531177	0.8894
60—64	199299	227383	426682	199198	235697	434895	0.8451
65—69	155091	180878	335969	164407	189587	353994	0.8672
70—74	117522	137336	254858	126199	143210	269409	0.8812
75—79	82970	90346	173316	89227	98059	187286	0.9099
80+	96925	126616	223541	96705	134269	230974	0.7202

Source: CBS, 2002.Analytical Report on Population Projection; Table 1.11; page 7.

The Sex ratio has been included having been calculated as the male population in a given age group divided by the female population in the same age group. The sex ratio is used in the calculation of the male population in the projection process.

APPENDIX 2: AGE-SPECIFIC FERTILITY RATES 2000-05

Age- group	ASFR
10--14	0.0024
15--19	0.1113
20--24	0.2008
25--29	0.1868
30--34	0.1465
35--39	0.1007
40--44	0.0441
45--49	0.0054
TFR	3.9900

Source: CBS, 2002.Analytical Report on Population Projection; Table3.1 on page 28.

APPENDIX 3: LIFE TABLE lx and Lx VALUES (COMBINED-with and without AIDS): PERIOD 2000-04:

AGE:	MALE			FEMALE		
	lx	Lx	Tx	lx	Lx	Tx
0	1.0000	0.9418	46.1049	1.0000	0.9493	52.8347
1	0.9169	3.5856	45.1631	0.9275	3.6355	51.8854
5	0.8759	4.3115	41.5775	0.8903	4.4020	48.2499
10	0.8487	4.2223	37.2660	0.8705	4.3398	43.8479
15	0.8403	4.1644	33.0437	0.8654	4.3032	39.5081
20	0.8255	4.0596	28.8793	0.8559	4.2122	35.2049
25	0.7983	3.9003	24.8197	0.8289	4.0045	30.9927
30	0.7618	3.6574	20.9194	0.7729	3.7041	26.9882
35	0.7012	3.2875	17.2620	0.7088	3.4041	23.2841
40	0.6138	2.8626	13.9745	0.6529	3.1402	19.8800
45	0.5312	2.4930	11.1119	0.6032	2.9200	16.7398
50	0.4660	2.1834	8.6189	0.5648	2.7172	13.8198
55	0.4074	1.8806	6.4355	0.5221	2.4947	11.1026
60	0.3449	1.5615	4.5549	0.4758	2.2609	8.6079
65	0.2797	1.2309	2.9934	0.4285	2.0068	6.3470
70	0.2126	0.8818	1.7625	0.3742	1.6928	4.3402
75	0.1401	0.5346	0.8807	0.3029	1.2909	2.6474
80	0.0737	0.2507	0.3461	0.2134	0.8260	1.3565
85	0.0265	0.0797	0.0954	0.1170	0.3935	0.5305
90	0.0053	0.0145	0.0157	0.0404	0.1190	0.1370
95	0.0005	0.0012	0.0012	0.0072	0.0180	0.0180

Source: CBS, 2002.Analytical Report on Population Projection; Tables2.6 and 2.7 on pages 24 and 25.

Note: T_x column has been added

APPENDIX 4: PROJECTED POPULATION

Matlab is a scientific software that is very friendly to use and it opens with a command window were one writes what is to be executed .It is capable of handling complex scientific operations and in this study it was used to take the projection matrix **L** (17×17) to powers which was then used in the projection of the population given in this appendix 4.

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		Base Pop			**K1**	
		2000			**2005**	
0—4	2351555	2314288	4665843	2232277	2196900	4429177
5—9	2261094	2233882	4494976	2089952	2064800	4154752
10—14	1932516	1916130	3848646	2221234	2202400	4423634
15—19	1691262	1850118	3541380	1736861	1900000	3636861
20—24	1386113	1624193	3010306	1545623	1811100	3356723
25—29	1201737	1339007	2540744	1385805	1544100	2929905
30—34	971438	997195	1968633	1206608	1238600	2445208
35—39	722167	762217	1484384	868249	916400	1784649
40—44	531011	581121	1112132	642472	703100	1345572
45—49	411606	452359	863965	491715	540400	1032115
50—54	318011	351610	669621	380680	420900	801580
55—59	250040	281137	531177	287095	322800	609895
60—64	199198	235697	434895	215343	254800	470143
65—69	164407	189587	353994	181415	209200	390615
70—74	126199	143210	269409	140907	159900	300807
75—79	89227	98059	187286	99365	109200	208565
80+	96705	134269	230974	36156	50200	86356
TOTAL	**14704286**	**15504079**	**30208365**	**15761754**	**16644800**	**32406554**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K2			K3	
		2010			2015	
0—4	2570233	2529500	5099733	2878213	2832600	5710813
5—9	1983876	1960000	3943876	2284291	2256800	4541091
10—14	2053109	2035700	4088809	1948925	1932400	3881325
15—19	1996385	2183900	4180285	1845278	2018600	3863878
20—24	1587269	1859900	3447169	1824434	2137800	3962234
25—29	1545287	1721800	3267087	1586931	1768200	3355131
30—34	1391408	1428300	2819708	1551561	1592700	3144261
35—39	1078489	1138300	2216789	1243631	1312600	2556231
40—44	772501	845400	1617901	959459	1050000	2009459
45—49	594990	653900	1248890	715280	786100	1501380
50—54	454754	502800	957554	550263	608400	1158663
55—59	343660	386400	730060	410542	461600	872142
60—64	247289	292600	539889	295970	350200	646170
65—69	196157	226200	422357	225208	259700	484908
70—74	155535	176500	332035	168136	190800	358936
75—79	111012	122000	233012	122477	134600	257077
80+	40333	56000	96333	45015	62500	107515
TOTAL	**17122286**	**18119200**	**35241486**	**18655612**	**19755600**	**38411212**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K4			K5	
		2020			2025	
0—4	3137218	3087500	6224718	3275205	3223300	6498505
5—9	2557985	2527200	5085185	2788256	2754700	5542956
10—14	2244027	2225000	4469027	2512907	2491600	5004507
15—19	1751670	1916200	3667870	2016861	2206300	4223161
20—24	1686351	1976000	3662351	1600753	1875700	3476453
25—29	1824046	2032400	3856446	1686013	1878600	3564613
30—34	1593353	1635600	3228953	1831441	1880000	3711441
35—39	1386791	1463700	2850491	1424121	1503100	2927221
40—44	1106484	1210900	2317384	1233772	1350200	2583972
45—49	888436	976400	1864836	1024559	1126000	2150559
50—54	661600	731500	1393100	821776	908600	1730376
55—59	496812	558600	1055412	597313	671600	1268913
60—64	353608	418400	772008	427812	506200	934012
65—69	269608	310900	580508	322073	371400	693473
70—74	192986	219000	411986	231055	262200	493255
75—79	132395	145500	277895	151959	167000	318959
80+	49696	69000	118696	53657	74500	128157
TOTAL	**20333068**	**21503800**	**41836868**	**21999534**	**23251000**	**45250534**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K6			**K7**	
		2030			**2035**	
0—4	3339423	3286500	6625923	3456681	3401900	6858581
5—9	2910832	2875800	5786632	2967919	2932200	5900119
10—14	2739024	2715800	5454824	2859446	2835200	5694646
15—19	2258559	2470700	4729259	2461772	2693000	5154772
20—24	1843209	2159800	4003009	2064073	2418600	4482673
25—29	1600483	1783300	3383783	1842803	2053300	3896103
30—34	1692816	1737700	3430516	1606894	1649500	3256394
35—39	1636920	1727700	3364620	1512992	1596900	3109892
40—44	1267125	1386700	2653825	1456367	1593800	3050167
45—49	1142483	1255600	2398083	1173238	1289400	2462638
50—54	947584	1047700	1995284	1056660	1168300	2224960
55—59	741928	834200	1576128	855503	961900	1817403
60—64	514439	608700	1123139	638929	756000	1394929
65—69	389626	449300	838926	468453	540200	1008653
70—74	275997	313200	589197	333981	379000	712981
75—79	181986	200000	381986	217383	238900	456283
80+	61652	85600	147252	73824	102500	176324
TOTAL	**23544086**	**31748900**	**61439363**	**32148720**	**34421800**	**66570520**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K8			K9	
		2040			2045	
0—4	3676667	3618400	7295067	3945122	3882600	7827722
5—9	3072173	3035200	6107373	3267625	3228300	6495925
10—14	2915521	2890800	5806321	3017990	2992400	6010390
15—19	2570006	2811400	5381406	2620375	2866500	5486875
20—24	2249776	2636200	4885976	2348687	2752100	5100787
25—29	2063584	2299300	4362884	2249274	2506200	4755474
30—34	1850242	1899300	3749542	2071963	2126900	4198863
35—39	1436248	1515900	2952148	1653784	1745500	3399284
40—44	1346166	1473200	2819366	1277816	1398400	2676216
45—49	1348578	1482100	2830678	1246486	1369900	2616386
50—54	1085150	1199800	2284950	1247317	1379100	2626417
55—59	953958	1072600	2026558	979750	1101600	2081350
60—64	736797	871800	1608597	821565	972100	1793665
65—69	581881	671000	1252881	671028	773800	1444828
70—74	401570	455700	857270	498768	566000	1064768
75—79	262970	289000	551970	316201	347500	663701
80+	88157	122400	210557	106667	148100	254767
TOTAL	**26639445**	**28344100**	**54983545**	**28340418**	**30157000**	**58497418**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K10			**K11**	
		2050			**2055**	
0—4	4238775	4171600	8410375	4501133	4429800	8930933
5—9	3506298	3464100	6970398	3767238	3721900	7489138
10—14	3210018	3182800	6392818	3444506	3415300	6859806
15—19	2712428	2967200	5679628	2885109	3156100	6041209
20—24	2394772	2806100	5200872	2478833	2904600	5383433
25—29	2348176	2616400	4964576	2394217	2667700	5061917
30—34	2258420	2318300	4576720	2357688	2420200	4777888
35—39	1851897	1954600	3806497	2018555	2130500	4149055
40—44	1471353	1610200	3081553	1647619	1803100	3450719
45—49	1183247	1300400	2483647	1362408	1497300	2859708
50—54	1152893	1274700	2427593	1094375	1210000	2304375
55—59	1126055	1266100	2392155	1040851	1170300	2211151
60—64	843708	998300	1842008	969803	1147500	2117303
65—69	748294	862900	1611194	768413	886100	1654513
70—74	575170	652700	1227870	641349	727800	1369149
75—79	392727	431600	824327	452964	497800	950764
80+	128274	178100	306374	159316	221200	380516
TOTAL	**30142504**	**32056100**	**62198604**	**31984378**	**34007200**	**65991578**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K12			K13	
		2060			2065	
0—4	4716445	4641700	9358145	4938972	4860700	9799672
5—9	4000344	3952200	7952544	4191747	4141300	8333047
10—14	3700779	3669400	7370179	3929821	3896500	7826321
15—19	3095818	3386600	6482418	3326180	3638600	6964780
20—24	2636630	3089500	5726130	2829161	3315100	6144261
25—29	2478312	2761400	5239712	2636089	2937200	5573289
30—34	2403863	2467600	4871463	2488324	2554300	5042624
35—39	2107331	2224200	4331531	2148641	2267800	4416441
40—44	1795924	1965400	3761324	1874874	2051800	3926674
45—49	1525646	1676700	3202346	1662952	1827600	3490552
50—54	1260160	1393300	2653460	1411111	1560200	2971311
55—59	988022	1110900	2098922	1137617	1279100	2416717
60—64	896360	1060600	1956960	850891	1006800	1857691
65—69	883228	1018500	1901728	816368	941400	1757768
70—74	658709	747500	1406209	757053	859100	1616153
75—79	505012	555000	1060012	518661	570000	1088661
80+	183732	255100	438832	204834	284400	489234
TOTAL	**33836314**	**35975600**	**69811914**	**35723296**	**37991900**	**73715196**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K14			K15	
		2070			2075	
0—4	5205597	5123100	10328697	5527194	5439600	10966794
5—9	4389629	4336800	8726429	4626580	4570900	9197480
10—14	4117916	4083000	8200916	4312163	4275600	8587763
15—19	3532044	3863800	7395844	3701068	4048700	7749768
20—24	3039699	3561800	6601499	3227792	3782200	7009992
25—29	2828599	3151700	5980299	3039059	3386200	6425259
30—34	2646724	2716900	5363624	2839999	2915300	5755299
35—39	2224058	2347400	4571458	2365608	2496800	4862408
40—44	1911607	2092000	4003607	1978769	2165500	4144269
45—49	1736108	1908000	3644108	1770139	1945400	3715539
50—54	1538095	1700600	3238695	1605747	1775400	3381147
55—59	1273960	1432400	2706360	1388602	1561300	2949902
60—64	979776	1159300	2139076	1097166	1298200	2395366
65—69	775003	893700	1668703	892333	1029000	1921333
70—74	699774	794100	1493874	664261	753800	1418061
75—79	596187	655200	1251387	551055	605600	1156655
80+	210380	292100	502480	241782	335700	577482
TOTAL	**37705157**	**40111900**	**77817057**	**39829319**	**42385200**	**82214519**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K16			**K17**	
		2080			**2085**	
0—4	5883236	5790000	11673236	6242226	6143300	12385526
5—9	4912319	4853200	9765519	5228828	5165900	10394728
10—14	4544937	4506400	9051337	4825718	4784800	9610518
15—19	3875668	4239700	8115368	4084914	4468600	8553514
20—24	3382260	3963200	7345460	3541849	4150200	7692049
25—29	3227172	3595800	6822972	3381539	3767800	7149339
30—34	3051297	3132200	6183497	3240189	3326100	6566289
35—39	2538424	2679200	5217624	2727252	2878500	5605752
40—44	2104687	2303300	4407987	2258383	2471500	4729883
45—49	1832286	2013700	3845986	1948936	2141900	4090836
50—54	1637222	1810200	3447422	1694744	1873800	3568544
55—59	1449703	1630000	3079703	1478075	1661900	3139975
60—64	1195879	1415000	2610879	1248447	1477200	2725647
65—69	999257	1152300	2151557	1089184	1256000	2345184
70—74	764808	867900	1632708	856454	971900	1828354
75—79	523120	574900	1098020	602284	661900	1264184
80+	223488	310300	533788	212181	294600	506781
TOTAL	**42145764**	**44837300**	**86983064**	**44661203**	**47495900**	**92157103**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K18			K19	
		2090			2095	
0—4	6592476	6488000	13080476	6948925	6838800	13787725
5—9	5547767	5481000	11028767	5859114	5788600	11647714
10—14	5136553	5093000	10229553	5449910	5403700	10853610
15—19	4337216	4744600	9081816	4616668	5050300	9666968
20—24	3733100	4374300	8107400	3963693	4644500	8608193
25—29	3541112	3945600	7486712	3732276	4158600	7890876
30—34	3395277	3485300	6880577	3555430	3649700	7205130
35—39	2896088	3056700	5952788	3034607	3202900	6237507
40—44	2426425	2655400	5081825	2576649	2819800	5396449
45—49	2091246	2298300	4389546	2246841	2469300	4716141
50—54	1802554	1993000	3795554	1934150	2138500	4072650
55—59	1530015	1720300	3250315	1627403	1829800	3457203
60—64	1272956	1506200	2779156	1317665	1559100	2876765
65—69	1137053	1311200	2448253	1159340	1336900	2496240
70—74	933561	1059400	1992961	974625	1106000	2080625
75—79	674441	741200	1415641	735134	807900	1543034
80+	244303	339200	583503	273545	379800	653345
TOTAL	**47292144**	**50292700**	**97584844**	**50005974**	**53184200**	**103190174**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K20			**K21**	
		2100			**2105**	
0—4	7332911	7216700	14549611	7757845	7634900	15392745
5—9	6175927	6101600	12277527	6517133	6438700	12955833
10—14	5755804	5707000	11462804	6067043	6015600	12082643
15—19	4898222	5358300	10256522	5173103	5659000	10832103
20—24	4219035	4943700	9162735	4476425	5245300	9721725
25—29	3962839	4415500	8378339	4218174	4700000	8918174
30—34	3747342	3846700	7594042	3978805	4084300	8063105
35—39	3177862	3354100	6531962	3349351	3535100	6884451
40—44	2699917	2954700	5654617	2827296	3094100	5921396
45—49	2385875	2622100	5007975	2500069	2747600	5247669
50—54	2078137	2297700	4375837	2206749	2439900	4646649
55—59	1746225	1963400	3709625	1876165	2109500	3985665
60—64	1401503	1658300	3059803	1503850	1779400	3283250
65—69	1200097	1383900	2583997	1276410	1471900	2748310
70—74	993748	1127700	2121448	1028644	1167300	2195944
75—79	767436	843400	1610836	782541	860000	1642541
80+	298177	414000	712177	311285	432200	743485
TOTAL	**52841057**	**56208800**	**109049857**	**55850888**	**59414800**	**115265688**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K22			K23	
		2110			2115	
0—4	8221289	8091000	16312289	8710035	8572000	17282035
5—9	6894778	6811800	13706578	7306736	7218800	14525536
10—14	6402185	6347900	12750085	6773231	6715800	13489031
15—19	5452921	5965100	11418021	5754129	6294600	12048729
20—24	4727586	5539600	10267186	4983269	5839200	10822469
25—29	4475482	4986700	9462182	4726598	5266500	9993098
30—34	4235206	4347500	8582706	4493556	4612700	9106256
35—39	3556276	3753500	7309776	3785371	3995300	7780671
40—44	2979987	3261200	6241187	3164020	3462600	6626620
45—49	2617993	2877200	5495193	2759393	3032600	5791993
50—54	2312297	2556600	4868897	2421464	2677300	5098764
55—59	1992319	2240100	4232419	2087573	2347200	4434773
60—64	1615747	1911800	3527547	1715812	2030200	3746012
65—69	1369632	1579400	2949032	1471526	1696900	3168426
70—74	1094118	1241600	2335718	1173956	1332200	2506156
75—79	810021	890200	1700221	861523	946800	1808323
80+	317335	440600	757935	328498	456100	784598
TOTAL	**59075173**	**62841800**	**121916973**	**62516692**	**66496800**	**129013492**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K24			**K25**	
		2120			**2125**	
0—4	9214733	9068700	18283433	9737417	9583100	19320517
5—9	7741063	7647900	15388963	8189662	8091100	16280762
10—14	7177862	7117000	14294862	7604580	7540100	15144680
15—19	6087606	6659400	12747006	6451342	7057300	13508642
20—24	5258581	6161800	11420381	5563336	6518900	12082236
25—29	4982201	5551300	10533501	5257460	5858000	11115460
30—34	4745672	4871500	9617172	5002366	5135000	10137366
35—39	4016360	4239100	8255460	4241665	4476900	8718565
40—44	3367882	3685700	7053582	3573298	3910500	7483798
45—49	2929819	3219900	6149719	3118535	3427300	6545835
50—54	2552156	2821800	5373956	2709800	2996100	5705900
55—59	2186117	2458000	4644117	2304139	2590700	4894839
60—64	1797876	2127300	3925176	1882728	2227700	4110428
65—69	1562667	1802000	3364667	1637419	1888200	3525619
70—74	1261373	1431400	2692773	1339449	1520000	2859449
75—79	924491	1016000	1940491	993282	1091600	2084882
80+	349457	485200	834657	374953	520600	895553
TOTAL	**66155918**	**70364000**	**136519918**	**69981429**	**74433100**	**144414529**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K26			**K27**	
		2130			**2135**	
0—4	10289059	10126000	20415059	10878399	10706000	21584399
5—9	8654152	8550000	17204152	9144048	9034000	18178048
10—14	8045216	7977000	16022216	8502090	8430000	16932090
15—19	6835005	7477000	14312005	7230827	7910000	15140827
20—24	5895401	6908000	12803401	6246155	7319000	13565155
25—29	5561707	6197000	11758707	5894673	6568000	12462673
30—34	5279030	5419000	10698030	5584920	5733000	11317920
35—39	4471044	4719000	9190044	4718330	4980000	9698330
40—44	3773871	4130000	7903871	3977641	4353000	8330641
45—49	3308433	3636000	6944433	3494055	3840000	7334055
50—54	2884267	3189000	6073267	3060633	3384000	6444633
55—59	2446708	2751000	5197708	2604129	2928000	5532129
60—64	1984399	2348000	4332399	2106945	2493000	4599945
65—69	1714425	1977000	3691425	1807214	2084000	3891214
70—74	1403778	1593000	2996778	1469869	1668000	3137869
75—79	1054611	1159000	2213611	1105567	1215000	2320567
80+	402610	559000	961610	427819	594000	1021819
TOTAL	**74003715**	**78715000**	**152718715**	**78253313**	**83239000**	**161492313**

APPENDIX 4 CONTINUED

	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
		K28			**K29**	
		2140			**2145**	
0—4	11511431	11329000	22840431	12184091	11991000	24175091
5—9	9668358	9552000	19220358	10231130	10108000	20339130
10—14	8983169	8907000	17890169	9498539	9418000	18916539
15—19	7641274	8359000	16000274	8073661	8832000	16905661
20—24	6608003	7743000	14351003	6982653	8182000	15164653
25—29	6244692	6958000	13202692	6606378	7361000	13967378
30—34	5918086	6075000	11993086	6269762	6436000	12705762
35—39	4991198	5268000	10259198	5289646	5583000	10872646
40—44	4197860	4594000	8791860	4440923	4860000	9300923
45—49	3683316	4048000	7731316	3887136	4272000	8159136
50—54	3232477	3574000	6806477	3407035	3767000	7174035
55—59	2763330	3107000	5870330	2918083	3281000	6199083
60—64	2243013	2654000	4897013	2379081	2815000	5194081
65—69	1919080	2213000	4132080	2042221	2355000	4397221
70—74	1549178	1758000	3307178	1644350	1866000	3510350
75—79	1157433	1272000	2429433	1220219	1341000	2561219
80+	447985	622000	1069985	469592	652000	1121592
TOTAL	**82759884**	**88033000**	**170792884**	**87544500**	**93120000**	**180664500**

APPENDIX 5: MEAN AGE OF FEMALES

AGE GROUP	FEMALES MID-POINT x	YEAR 2000 POPULATION f	x*f	YEAR 2005 POPULATION f	x*f
0—4	2.5	2314288	5785720	2196900	5492250
5—9	7.5	2233882	16754115	2064800	15486000
10—14	12.5	1916130	23951625	2202400	27530000
15—19	17.5	1850118	32377065	1900000	33250000
20—24	22.5	1624193	36544343	1811100	40749750
25—29	27.5	1339007	36822693	1544100	42462750
30—34	32.5	997195	32408838	1238600	40254500
35—39	37.5	762217	28583138	916400	34365000
40—44	42.5	581121	24697643	703100	29881750
45—49	47.5	452359	21487053	540400	25669000
50—54	52.5	351610	18459525	420900	22097250
55—59	57.5	281137	16165378	322800	18561000
60—64	62.5	235697	14731063	254800	15925000
65—69	67.5	189587	12797123	209200	14121000
70—74	72.5	143210	10382725	159900	11592750
75—79	77.5	98059	7599573	109200	8463000
80+	82.5	134269	11077193	50200	4141500
TOTAL		**15504079**	**350624808**	16644800	390042500
MEAN AGE=		**22.615**		**23.43329**	

APPENDIX 5: CONTINUED

AGE GROUP	FEMALES MID-POINT x	YEAR 2020 POPULATION f	x*f	YEAR 2050 POPULATION f	x*f
0—4	2.5	3087500	7718750	4171600	10429000
5—9	7.5	2527200	18954000	3464100	25980750
10—14	12.5	2225000	27812500	3182800	39785000
15—19	17.5	1916200	33533500	2967200	51926000
20—24	22.5	1976000	44460000	2806100	63137250
25—29	27.5	2032400	55891000	2616400	71951000
30—34	32.5	1635600	53157000	2318300	75344750
35—39	37.5	1463700	54888750	1954600	73297500
40—44	42.5	1210900	51463250	1610200	68433500
45—49	47.5	976400	46379000	1300400	61769000
50—54	52.5	731500	38403750	1274700	66921750
55—59	57.5	558600	32119500	1266100	72800750
60—64	62.5	418400	26150000	998300	62393750
65—69	67.5	310900	20985750	862900	58245750
70—74	72.5	219000	15877500	652700	47320750
75—79	77.5	145500	11276250	431600	33449000
80+	82.5	69000	5692500	178100	14693250
TOTAL		**21503800**	**544763000**	**32056100**	**897878750**
MEAN AGE=		**25.33334**		**28.00961**	

APPENDIX 5: CONTINUED

AGE GROUP	FEMALES MID-POINT x	YEAR 2080 POPULATION f	x*f	YEAR 2090 POPULATION f	x*f
0—4	2.5	5790000	14475000	6488000	16220000
5—9	7.5	4853200	36399000	5481000	41107500
10—14	12.5	4506400	56330000	5093000	63662500
15—19	17.5	4239700	74194750	4744600	83030500
20—24	22.5	3963200	89172000	4374300	98421750
25—29	27.5	3595800	98884500	3945600	108504000
30—34	32.5	3132200	101796500	3485300	113272250
35—39	37.5	2679200	100470000	3056700	114626250
40—44	42.5	2303300	97890250	2655400	112854500
45—49	47.5	2013700	95650750	2298300	109169250
50—54	52.5	1810200	95035500	1993000	104632500
55—59	57.5	1630000	93725000	1720300	98917250
60—64	62.5	1415000	88437500	1506200	94137500
65—69	67.5	1152300	77780250	1311200	88506000
70—74	72.5	867900	62922750	1059400	76806500
75—79	77.5	574900	44554750	741200	57443000
80+	82.5	310300	25599750	339200	27984000
TOTAL		**44837300**	**1253318250**	**50292700**	**1409295250**
MEAN AGE=		**27.95258**		**28.02187**	

APPENDIX 5: CONTINUED

AGE GROUP	FEMALES MID-POINT x	YEAR 2100 POPULATION f	x*f	YEAR 2145 POPULATION f	x*f
0—4	2.5	7216700	18041750	11991000	29977500
5—9	7.5	6101600	45762000	10108000	75810000
10—14	12.5	5707000	71337500	9418000	117725000
15—19	17.5	5358300	93770250	8832000	154560000
20—24	22.5	4943700	111233250	8182000	184095000
25—29	27.5	4415500	121426250	7361000	202427500
30—34	32.5	3846700	125017750	6436000	209170000
35—39	37.5	3354100	125778750	5583000	209362500
40—44	42.5	2954700	125574750	4860000	206550000
45—49	47.5	2622100	124549750	4272000	202920000
50—54	52.5	2297700	120629250	3767000	197767500
55—59	57.5	1963400	112895500	3281000	188657500
60—64	62.5	1658300	103643750	2815000	175937500
65—69	67.5	1383900	93413250	2355000	158962500
70—74	72.5	1127700	81758250	1866000	135285000
75—79	77.5	843400	65363500	1341000	103927500
80+	82.5	414000	34155000	652000	53790000
TOTAL		**56208800**	**1574350500**	**93120000**	**2606925000**
MEAN AGE=		**28.00897**		**27.99533**	