MORTALITY ESTIMATIONS IN KENYA WITH SPECIAL REFERENCE TO CAUSES OF DEATH.

BY

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DECLARATION

This thesis is my original work and to the best of my knowledge has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as University Supervisors.

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ABSTRACT:

As in most developing countries, mortality data in Kenya has often been said to be inaccurate and incomplete. The system of registration of vital events, in particular registration of deaths, has not been developed to the extent that it covers every death which occurs. Therefore, levels and trends of mortality in Kenya have been learned through the widespread adoption of indirect methods of estimating demographic parameters from limited data.

In this study, four "Indirect" methods of mortality estimation have been derived, discussed and applied to the mortality data in Kenya in order to estimate the level of mortality which prevailed in the country in 1979. Three of the four methods of analysis namely:

I) The Bennett-Horiuchi Method of estimating the completeness of death registration;

II) The Bennett-Horiuchi Method of constructing life tables from incomplete death registration data;

and III) The Preston Census-based Method of constructing life tables; are generalizations of the stable population theory, and unlike the previous indirect methods which used a constant population growth rate in the estimation of mortality

the three methods use age specific population growth rates.

A study of the completeness of death registration in Kenya in 1979 relative to the 1979 Population Census enumerated by age and sex has indicated that the completeness was poor. It has been estimated to have been equal to 22.2 percent for males and 12.7 per cent for females.

A study of the life expectancy estimates obtained by the two indirect methods of constructing life tables has revealed that below age 35 for males and age 45 for females, the life expectancy estimates due to the Bennett-Horiuchi method are systematically relatively higher than the corresponding values due to the Preston Census-based Method. And after these two ages for males and females respectively, the order changes (i.e., life expectancy estimates due to the Bennett-Horiuchi Method becomes systematically relatively lower than the corresponding values due to the Preston Census-based Method). It is further observed that at all ages, the life expectancy estimates obtained by the Bennett-Horiuchi Method using the 1979 registered deaths agree relatively better to the corresponding life expectancy values in the Kenya National "Model" Life Tables - 1979, than the corresponding life expectancy estimates due to the Preston Census-based Method, using the 1969 and 1979 population censuses classified by age and sex.

The cause of death analysis is done using the fourth method of analysis: The single and multiple decrement approaches. The cause of death analysis has shown that for all groups of causes of death studied except for accidents, the risk of dying is always high at the beginning and at the end of the life span, lowest at puberty, and low with an upward slope during the long period of adulthood. For accident, the risk of dying is high during the active years of life and higher among males than females. Infact it is the leading cause of death for males between age 15 years and age 45 years. Among females, it is the third leading cause of death at this age interval.

Further, as for the risk of dying, a study of the gain in life expectancy when a particular group of causes is hypothetically eliminated from society has revealed that there exist age, sex and cause of death differentials in mortality. And that like in most developing countries, the major causes of death in Kenya are infective and parasitic, respiratory and circulatory system diseases.

CHAPTER 1

INTRODUCTION

World mortality trends over the past several decades indicate that the world has experienced an appreciable reduction in mortality and hence an increase in life expectancy at birth. This reduction has been attributed to socio-economic development and technological advances in the prevention and control of diseases and the growth and expansion of public health and medical services. Estimated life expectancy at birth in 1950 - 1955 and 1970 - 1975 show that in the developed countries, life expectancy increased from 65.2 years to 71.3 years for both males and females. While it increased from 42.4 years to 53.1 years in the less developed countries. In Africa which is believed to have the highest level of mortality in the world, life expectancy at birth increased from 37.3 years to 46.4 years, and it increased from 35.7 years to 44.7 years in Eastern Africa.[1]

Within Eastern Africa, mortality studies in Kenya have shown that by the time of the first census (1948), the crude death rate was 25 per 1000; infant mortality rate was about 184 per 1000, and life expectancy at birth 35 years. In 1968, the crude death rate was 17 per 1000 population, infant mortality rate 119 per 1000, life expectancy at birth was 49 years. And estimates from the 1979 National Demographic Survey suggest a crude death rate of 14 deaths per 1000; infant mortality rate of about 83 per 100, and a further rise in life expectancy at birth to 51.2 years for males and 55.8 years for females.[2] Consistent with the classical demographic theory, this steady decline in mortality in Kenya has been associated with the general improvement in social welfare and economic development. Some of the specific factors shown to be important are improvement in infant and childhood nutrition, the rising levels of female education and the eradication and control of specific diseases.

1.1 Problem Statement:

Although the study of mortality has for long occupied the minds of Demographers and Physicians alike, most mortality studies in Kenya have concentrated on mortality levels and differentials, and in particular infant and child mortality, without focussing attention on the contribution of various underlying causes of death to variations in mortality. As pointed out by Preston (1976)[3] "Ignoring causes of death to variations in the study of mortality is somewhat akin to ignoring fecundity, exposure, contraceptive effectiveness and fetal wastages in the study of fertility". Hence the motivation to carry out this study which will try, among other things, to determine the likelihood that a person will die from a given cause or group of causes of death at a given age and the typical length by which life is shortened as a consequence of various causes of death in Kenya.

1.2 OBJECTIVES:

The main objectives of this research is to estimate mortality in particular adult mortality for Kenya by:

(i) investigating the completeness of death registration using recorded deaths from the office of Registrar General and the population censuses of 1969 and 1979.

(ii) constructing life tables for Kenya based on only the two censuses of 1969 and 1979.

(iii) constructing life tables using total number of deaths which occurred in 1979 and then compare it with the national life tables (1979) prepared by the Central Bureau of Statistics and the tables derived by the censuses based method stated in (ii) above.

(iv) constructing the single and multiple decrement life tables by cause of death which will make it possible to:

(a) determine the mortality differentials by cause of death,

(b) show the variations in gain in life expectancy when various causes of death are eliminated.

1.3 THEORETICAL FRAMEWORK:

The environment and demographic factors are linked together in many practical ways of human life and his existence. Thus, man's existence is primarily dependent on the existing environmental and demographic conditions. Thus; environmental and demographic factors are likely to affect (either independently or jointly) the chances of dying from a given cause or group of causes of death in a given society. This is a conceptual proposition which cannot be tested in its presented form without further definition of its key concepts. Where the key concepts are environment, demography and death.

Environmental factors are factors relating to, or produced by environment. And environment has been defined as "the aggregate of all external conditions and influences affecting the life and development of an organism"[4]. Environment thus embraces both the physical (natural) on the one hand, that is, all those aspects of the surroundings that are there independently of man, such as climate of a place and its altitude, and the biological environment on the other hand. The biological environment embraces the form of life in an area, its number, type and spatial distribution and mode of life. The environment of an area has an important influence on the life of the inhabitants. For instance, the prevalence or absence of certain diseases may be related to the altitude, or the availability of open water, humidity, rainfall and so on. Further, the ability of a country to provide medical facilities for its people may also be influenced by the country's available natural resources from which she must find funds to pay for the facilities and services.

Demography may be regarded as a "kind of biosocial bookkeeping, a continuous inventory analysis of the human population and its vital processes, collectively considered."[5] There are two phases of demography, a static and a dynamic. The first ascertains and describes the state of the population. This is the function of censuses enumeration and analysis which are not only exceedingly important and useful in their own right, but are indispensable basis for all studies of vital statistics. The dynamic phase of demography has its functions in the statistical analysis of the vital events.

According to Henin,[6] demography may simply be defined either narrowly or broadly. From the narrow perspective demography is defined as a study of populations as closed systems. That is, like any other system, a population may be viewed as being composed of two types of elements: structures and processes. Where the structural elements of a population are:-

(i) Its size (the number of people).

(ii) Its distribution (arrangement of people in space), and

(iii) Its biological composition (its age and sex structure).

And the processes are: fertility, mortality and migration.

In a broader sense, demography is defined to include additional characteristics of the population such as marital and family, place of birth, literacy, employment status, occupation, industry and income among others. Thus, from the broader perspective populations are treated as open systems and one can study how demographic structures and processes affect factors external to the population system and how these, in turn, affect demographic structures and processes. For example, the lower the standard of living of a country, the poor the sanitary conditions hence the prevalence of diarrhoeal diseases as major causes of death. In order, therefore, to study the variations in the chances of dying from various causes of death by age and sex, it would be advisable or reasonable to use demography as broadly defined.

From the definitions of environment and demography, however, we realise that environmental and demographic factors are by no means sharply demarcated. Hence for the purposes of this study, demographic factors will be used mainly to refer to "inborn" biological factors. While environmental factors will refer to all factors relating to, or produced by the environment as defined above.

The UN and WHO proposed definition of "death" which will be used in this study is as follows: "Death is the permanent disappearance of all evidence of life at any time after birth has taken place (post-natal cessation of vital functions without capacity of resuscitation)"[7]. This permanent disappearance of all evidence of life has many causes, which in this study have been summed up under two interacting processes:- as demographic (in-born biological) and environmental conditions. Although it is impossible clearly to separate the influences of inborn biological factors and environmental factors on mortality as the influences are inextricably interwoven, there are certain groups of circumstances bearing on life and its termination in which inborn biolcgical characteristics play the dorminant role. Similarly there are some circumstances of death which are purely or predominantly environmental in origin.

A preliminary model can thus be formulated to explain differentials in mortality by sex, cause of death and age. Let (E) be the environmental component of mortality (M), and (D) be the demographic component. And if we introduce the obstetrical component (O) early in life, then mortality rate can be represented by the formula

$$M = D + \underline{E} + O.$$

1.4 LITERATURE REVIEW:

One of the most valuable methods of mortality analysis is the life table methodology whose introduction in demographic analysis was by John Graunt[8] in the seventeenth century. Graunt's successors laid the cornerstone of the life insurance business and in the three succeeding centuries, insurance companies, government experts and academic scholars have brought the life table to maturation as a valuable tool of demographic analysis. It was more so brought to a sophisticated level by Lotka[9] in his two papers of 1907 and 1911. Indeed his "contribution to demography can be likened in some respects to that of Newton in physics. Both achieved a synthesis in analytical theory which had far reaching significance, and both set a frame for new empirical evidence".[10]

In some of its latest applications, life table methodology has been used in the study of mortality by cause of death (Preston[11] et al 1972, Manton[12] et al 1976 and Manton[13] et al 1982).

Most mortality studies treat mortality as a single unitary force, the intensity of which has been found to vary with age, sex, place of birth and other variables and which has undergone a historic decline over-time. On the other hand, however, mortality could be viewed not as a single unitary force, but as an agglomeration of semi-independent forces, each force being represented by death from a particular cause. According to this view, therefore, the sharp decline in mortality in Kenya since 1962,[14] is simply an indirect consequence of the virtual elimination of those deaths due to certain specific causes, and a great decrease in the deaths due to certain other diseases and disorders by use of medical technology.

In a study of the future outlook of mortality decline in the world, Bourgeois - Pichat[15] divided causes of death into two groups: namely the exogeneous causes and the endogeneous causes. Under the exogeneous deaths were:

(i) Deaths due to infective and parasitic diseases
(ii) Deaths due to diseases of the respiratory systems.
(iii) Deaths due to accidents, poisonings and violence (external causes).

And under the endogeneous deaths were:

(i) Deaths due to neoplasms
(ii) Deaths due to diseases of circulatory system
(iii) Deaths due to all other causes.

He found that while deaths due to exogeneous causes were declining rapidly in the developed countries, deaths due to endogeneous causes were on the increase. He further noted that some diseases are caused by climatic conditions, diet or the kind of work in which a person is engaged in.

In a comparative analysis of cause of death for selected countries, John[16] (1973) found that causes of death varied, depending on the state of the standard of living, the environment, public health measures and the demographic structure of the country under study. He found that in developing countries where there is a youthful age structure, tropical climate, poor environmental conditions and scarcity of health personnel, the overriding causes of death were infective and parasitic diseases with peri-natal and respiratory diseases as other major causes of death. In the developed countries on the other hand, he found major causes of death to be due to degenerative diseases, diseases of the respiratory and circulatory systems and cancer of all forms. He also found that accidents accounted for a significant percentage of deaths in the developed countries.

A joint study by WHO and the UN Department of Economic and Social Affairs[17] (1979) on morbidity and causes of death found that the risk of dying varies with both disease and circumstance, as well as age and sex. On major causes of death, the study found that while degenerative diseases (mainly cardio-vascular diseases and cancers) were the major causes of death in the more developed countries, infective and parasitic diseases were prominent in the less developed countries. Among the reasons given for these differential causes of death in the developed and less developed regions were:

(i) different age structures in the two regions, and

(ii) availability of health services.

The degenerative diseases are much more common among the older people, and the more developed countries have significantly older age structures (hence proportionately more older people) than the less developed countries. Secondly, the vigorous public health programmes in the more developed regions have done much to reduce or eliminate the threats posed by many infectious and parasitic diseases thus lowering the chances of dying from these diseases. These diseases have been found to have a disproportionately large effect among the younger age groups, which makes up a large percentage of populations of the less developed than developed countries. Moreover, infectious and parasitic diseases endanger most individuals who are under-nourished or malnourished, and nutritional deficiencies are prevalent among the less developed countries.

In another study by the UN[18] (1979) for 37 developed countries, it was found that the chances of dying from a particular cause of death vary with both age and sex. The study for instance showed that after the first year of life and continuing to the twenties, accidents were usually the leading causes of death for both males and females, with malignant neoplasms generally in the second place. In the thirties, cardio-vascular diseases and malignant neoplasms supercede accidents as the leading cause of death among males. And from there to the end of the life span, cardio-vascular diseases were found to, usually followed by malignant neoplasms as the two leading causes of death among males. Among females, it was found that malignant neoplasms were the leading causes of death during the twenties followed by either accidents or cardio-vascular diseases. While neoplasms remained the leading cause of death up to the fifties or sixties, cardio-vascular diseases were found to assume an increasing proportion of the total. It was also found that while the middle ages age specific death rates for malignant neoplasms were somewhat higher for females than for males, male death rates for malignant neoplasms eventually exceeded those for females in advanced ages. Also in middle ages, it was observed that deaths from cardio-vascular diseases were higher for males than for females although the difference was found to diminish thereafter.

Hauser[19] (1968) had also found that for both males and females in the United States of America, the percentage of deaths attributable to major cardio-vascular - renal diseases increased with age. In contrast, he found that the percentage of deaths attributable to malignant neoplasms which accounted for a larger proportion of the deaths of the youth decreased with age. He also found that for all causes of death, mortality for all adult males was higher than that of adult females and that the differential was much greater at younger ages.

Although epidemiological studies of mortality by cause in Kenya have been limited by the availability of data, a few studies are available which have been based mainly on hospital records. Grounds[20] (1964) analyzed child mortality under 6 years of age in government hospitals in Kenya using the 1962 registers. He found that respiratory tract infections was the leading cause of death followed by gastroenteritis, malnutrition, malaria, whooping cough, meningitis, prematurity, burns and measles in that order.

In a study of patterns of mortality and morbidity in Kenya, Bonte[21] (1978) found respiratory diseases, infective and parasitic diseases and the diseases of the digestive system to be the leading causes for all hospital deaths in that order. The three constituted together nearly three quarters of all hospital deaths. Thus as in most other developing countries, respiratory diseases, infective and parasitic diseases and the digestive system diseases were the major causes of death. Of the dorminant killing dieseases, Bonte found that deaths due to pneumonia represented a quarter of all deaths with females more than males.

A Ministry of Health - in - Patient Report[22] (1978) shows that among the categories of diseases, the largest group were infectious and parasitic diseases which accounted for 20.8 per cent of all reported hospital discharges in Kenya, followed by respiratory system diseases. A study of the age patterns of mortality reflects the predominance of acute infectious diseases in children coupled with the case fatality ratio highest among the young age group. Regarding sex ratios, it was found that males except for a few diseases predominated.

Despite data limitations, the available literature clearly indicates that infectious and parasitic diseases, respiratory diseases and digestive system diseases — which have been largely eradicated or eliminated as significant causes of death in the developed regions — still account for a very large proportion of all deaths in developing countries, especially among the very young. Secondly, from the available literature, we note that although both males and females have many risks in common. each has its own peculiar risks hence differentials in mortality by sex.

1.5 HYPOTHESES:

If causative factors of mortality throughout the life span are looked as to belong to the two groups namely:- environmental factors and demographic factors and if although..

males and females have many risks of death in common, each sex has its own peculiar risks, then we hypothesize that

i) Kenya being a developing country, infective - parasitic and respiratory diseases (which are environmental in origin) are the major causes of death particularly at the early years of life;

ii) the risk of dying from accidents as a cause of death is high at the productive years of life (15 to 64 years) and is higher among males to females due to the greater exposure of men to environmental hazards as usually man is the breadwinner in most families in Kenya.

iii) the risk of dying from a given cause of death varies with age as well as sex.

1.6 SIGNIFICANCE OF THE STUDY:

As in most developing countries , a lot of doubt has been cast on the completeness of registration of vital events in Kenya. Hence, a study of the completeness of death registration will help to measure its coverage in view of improving it. Secondly, if the level of mortality is associated with the structure of the causes of a death; a study of mortality by cause will lead to the assessment of future prospects of mortality decline. since the study will identify the leading causes of death in Kenya. Finally, the study will help the government to come up with an appropriate life table for Kenya which can be used in life insurance businesses.

1.7 DATA SOURCE AND QUALITY:

1.7.1 Data Source:

This study draws upon the data from two major sources: Censuses and vital registration. The history of censuses in Kenya goes back to 1948 when the first census was taken. The second, third and fourth censuses were conducted in 1962, August 1969 and August 1979 respectively. It is upon the population by sex and age as enumerated in the last two censuses that this study is based.

Registration of vital events in Kenya is mainly carried out by the Registrar General's Office. According to the Registrar General's[23] 1977 Annual Report, in all districts except in Marsabit, Mandera, Wajir, Isiolo, Samburu, Turkana and Tana River districts, the Department had established its own registries of births and deaths. It was further reported that where such registries had not been established, registration is carried out by the District Commissioners who act as District Registrars.

Working under the supervision of the District Registrar is a number of Deputy Registrars who have been given a short course in their duties. The Deputy Registrars are mainly school teachers, nurses, health personnel who undertake registration duties on a part-time basis in addition to their employment. There is no salary for the work of registration other than small honoraria payment of 25 cents per registration, which helps to defray the cost of incidental expenses such as postages, etc. Of late, the government has sought the assistance of Assistant Chiefs in the vital registration exercise.

Two types of Forms are used in the field. Deaths are reported either:

(a) On Form A2 where a qualified medical practitioner certifies the death and gives a medical cause of death which is coded according to the international statistical classification; or

(b) On Form A3 where no medical practitioner certifies death. In the latter case the cause of death is determined by a description of the fatal symptoms (or Syndromes).

Once the information has been returned to the central registry, the returns are passed to the machine room. The arrangements for compiling the statistical data is that the information from the register pages is placed directly on to paper tape by Flexowriter, which is subsequently processed for use in a computer. Data used in this study was obtained from the Central Bureau of Statistics of Kenya as the Number of deaths by cause which occurred in 1979 and were reported in the same year.

1.7.2 Quality of Data:

In Kenya as in many other developing countries, demographers are often confronted with a paucity of data which preclude as a complete a demographic profile as may be desired. Birth and death registration systems function poorly, thereby resulting in the incomplete recording of vital events. Hence, for those data which are available, doubt is often cast upon their validity. Further difficulties arise when ages are misstated, either in censuses, surveys, or the registration of deaths and when respondents to surveys and censuses misperceive the timing of vital events. The data are also not available for a sufficiently long period and often the available information is not tabulated in sufficient detail.

The efficiency of the cause of death coding and the clarity and accuracy of the cause of death certification by laymen (Deputy Registrars) affect the counting of deaths to a specific cause of death. It is not surprising then when it is found that diseases such as cardiovascular diseases are more prevalent among children than in adults.

Very often, death is the result, not of a single condition, but rather a series of diseases. Further difficulties thus arise in selecting the cause of death for such a series — even experts opinions often disagree.

Just like in many other developing countries, it has been shown that the quality of data more particularly the cause of death data is poor in Kenya. But demographic data are never perfectly accurate, and the choice is between neglecting them altogether and producing qualified statements about the tendencies they suggest. Obviously, the the latter course is pursued here.

1.8 SUMMARY AND SCOPE OF THE STUDY:

1.8.1 Summary of the Chapters:

Chapter one deals mainly with the problem studied, the objectives and the hypotheses tested in this study. It also contains the theoretical statement, literature review and the data Source and Quality.

Chapter two mainly deals with the methods of analysis. Detail derivation and discussion of four methods of analysis is given. Methods I, II and III are derived from the extension of the stable population theory. Method IV (a and b) constructs life tables by cause of death using results of Method II as intermediate results.

Chapter three discusses the results obtained by Methods I, II and III when applied to the population of Kenya in 1979.

Chapter four discusses the results obtained by the application of Method IV (a and b) to the number of registered deaths (current) in Kenya in 1979.

Chapter five deals with a summary of the findings, conclusions and recommendations that have arisen from the study.

1.8.2 Scope and Limitations of The Study:

A study of mortality needs good statistical data on population (by different characteristics) and on deaths (by similar characteristics). While the first set of data is easily available in Kenya from censuses and surveys, the second set is not available. Registration of deaths in Kenya as in many other developing countries is poor. And even when a death is registered, it might be attributed due to a different cause than the true underlying cause.

Second, in this study we shall mainly rely on hospital records and Registrar General's records on death which occurred in 1979 and were registered in the same year by cause. But this type of data may not be representative of the whole population in Kenya.

Despite all these, we can however make some inference regarding cause of death by age and sex from this registration data by using indirect methods of mortality estimations. The methods are discussed in Chapter II and their limitations given in Chapter V.

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CHAPTER II

METHODS OF ANALYSIS

2.1 INTRODUCTION

The inadequecy or, occasionally, the complete lack in many developing countries of the data traditionally required for the estimation of mortality has led demographers to develop alternative methods of estimation known as "Indirect". The art and science of indirect estimation has been developed over the past two decades by William Brass, Ansley Coale, Samuel Preston, and others. Stable population theory, which assumes constant fertility and mortality schedules, has been the major workhouse in the evolution of this field of indirect estimation. The creative exploitation of the power of stable population theory has given rise to innumerable methods which have enabled demographers to glean significant amounts of information from less perfect data.

It should be noted however that there was an awareness of the limitation of this theory. The theory worked quite well with data from the developed countries with fixed fertility and mortality schedules but not so well with data from the rest of the world. With this in mind, Coale[1] (1963) introduced the notion of Quasi-Stable Population theory where the assumption was of contant fertility and declining mortality.

Recently, however, more and more countries, Kenya included, have been experiencing rapidly declining mortality and/or declining or fluctuating fertility and thus have undergone a radical departure from stability or quasi-stability. Consequently, previously successful methods, based on stable or quasi-stable population theory, are with greater frequency ill-suited to the task for which they were devised.

Bennett and Horiuchi[2] (1981) introduced the use of age specific population growth rates into indirect estimation of mortality in order to circumvent this increasingly limited applicability of stable population techniques. They specifically used this technique to study the completeness of death registration. Again with the use of this technique, Preston[3] (1982) constructed life tables using only two consecutive censuses. Further, Bennett and Horiuchi[4] (1982) found that it was possible to construct life tables from incomplete death registration data and two consecutive censuses with the aid of the technique.

Elaborate work on this theory has now been published in the Population Index by Preston and Coale[5] (1982).

Apart from mortality estimation, the technique can be applied to detect age mis-reporting, in the estimation of SMAM (singulate Mean Age at Marriage), migration rates etc.

In this study, mortality estimations will be made using the age specific growth rates technique by three approaches.

By approach or Method I, the completeness of death registration in Kenya in 1979 shall be approximated.

By Method II, Kenya's life tables will be constructed from the number of registered deaths in 1979 and the 1979 census data.

By Method III, Kenya's life tables will be constructed based on the 1969 and 1979 censuses data.

Finally, the single and multiple decrement approaches (Method IV, a & b) will be applied to the life tables obtained by Method II to construct life tables by causes of death.

2.2 MATHEMATICAL MODEL OF ANALYSIS

Let $N(x)$ be the number of persons age x, $\mu(x)$ be the age specific mortality rate at exact age x, $D^*(x)$ be the number of deaths experienced by persons aged x and r be the constant growth rate.

In a stable population,

$$N(x) = N(o)\, e^{-rx}\, p(x) \quad \ldots \quad (2.1)$$

where $p(x)$ is the probability of surviving up to age x from birth.

Differentiating equation (2.1) with respect to x, we get

$$\frac{dN}{dx} = N(o) \left[-r\, e^{-rx} p(x) + e^{-rx} \frac{dP}{dx} \right]$$

$$= N(o) \left[-r\, e^{-rx} p(x) + e^{-rx} \frac{p(x)}{p(x)} \frac{dP}{dx} \right]$$

$$= N(o) \left[-r\, e^{-rx} p(x) + e^{-rx} p(x) \frac{d}{dx} \log p(x) \right]$$

$$= N(o)\, e^{-rx} p(x) \left[-r + \frac{d}{dx} \log p(x) \right]$$

$$= N(x) \left[-r + \frac{d}{dx} \log p(x) \right] \quad \ldots \qquad (2.2)$$

But

$$\mu(x) = \frac{D^*(x)}{N(x)}$$

$$= - \frac{1}{\ell(x)} \frac{d\ell}{dx}$$

$$= - \frac{d}{dx} \log \ell(x)$$

$$= - \frac{d}{dx} \log \frac{\ell(x)}{\ell(o)} \cdot \ell(o)$$

$$= - \frac{d}{dx} \log \frac{\ell(x)}{\ell(o)} \quad \text{since } \ell(o) \text{ is a constant.}$$

$$= - \frac{d}{dx} \log p(x) \quad \ldots\ldots \qquad (2.3)$$

Therefore (2.2) becomes

$$\frac{dN}{dx} = N(x) \left[-r - \mu(x) \right]$$

which implies that

$$\frac{1}{N(x)} \frac{dN}{dx} = -r-\mu(x) \quad \ldots\ldots\ldots\ldots \qquad (2.4)$$

Thus the relative change in the number of persons at age x diminishes at a rate of $r + \mu(x)$.

Suppose now that the rate of increase is no longer a constant, but rather a function of age. Then equation (2.4) can be modified to

$$\frac{1}{N(x)} \frac{dN}{dx} = -r(x) - \mu(x)$$

i.e

$$\frac{d}{dx} \log N(x) = -r(x) - \mu(x) \quad \ldots. \quad (2.5)$$

If $a \leq x \leq a+n$, then integrating equation (2.5), we have

$$\log N(x) \Big|_a^{a+n} = \int_a^{a+n} \left[-r(x) - \mu(x) \right] dx$$

which implies that

$$\log \frac{N(a+n)}{N(a)} = -\int_a^{a+n} r(x)\, dx - \int_a^{a+n} \mu(x)\, dx$$

i.e.

$$N(a+n) = N(a)\, e^{-\int_a^{a+n} r(x)dx},\ {}_nP_a \quad \ldots\ldots. (2.6)$$

where

$${}_nP_a = e^{-\int_a^{a+n} \mu(x)\, dx} \quad \ldots\ldots\ldots \quad (2.7)$$

is the probability of surviving from age 'a' to age 'a+n'.

If $0 \leq x \leq a$, then we have

$$N(a) = N(o)\, e^{-\int_o^a r(x)dx}.\ P(a) \quad \ldots. \quad (2.8)$$

where

$$P(a) = e^{-\int_0^a \mu(x)dx},$$

is the probability of surviving from birth to age 'a'. Note that equation (2.8) is a generalization of equation (2.1).

An alternative approach to obtain the results derived above, is as follows:-

Let $N(x, t)$ be the number of persons aged x at time t. Using the notion of differentials,

$$d\,N(a, t) = \frac{\partial}{\partial a} N(a, t)\,da + \frac{\partial}{\partial t} N(a, t)\,dt \quad \ldots \quad (2.9)$$

At time t + dt, the number of persons aged 'a' at time t who have died is

$$D^*(a, t) = N(a, t) - N(a+da, t+dt) \quad \ldots \quad (2.10a)$$

assuming closed population and the same cohort. Re-arranging equation (2.10a), we get

$$-D^*(a, t) = N(a+da, t+dt) - N(a,t) \quad \ldots \quad (2.10b)$$

By the principle of differential calculus, if

$$df = f(x+h, y+h) - f(x,y)$$

then

$$df = h\frac{\partial f}{\partial x} + k\frac{\partial f}{\partial y} \quad \ldots \quad (2.11)$$

$$\text{as} \quad (h, k) \to 0.$$

So equation (2.10b) becomes

$$-D^*(a,t) = \frac{\partial N}{\partial a}\,da + \frac{\partial N}{\partial t}\,dt \quad \ldots \quad (2.12)$$

$$\text{as} \quad da = dt \to 0.$$

Therefore

$$-\frac{D^*(a,t)}{N(a,t)da} = \left(\frac{\partial N}{\partial a} + \frac{\partial N}{\partial t}\right) \cdot \frac{1}{N(a,t)}$$

i.e.;

$$-\mu(a,t) = \frac{1}{N(a,t)}\frac{\partial N}{\partial a} + \frac{1}{N(a,t)}\frac{\partial N}{\partial t}$$

But

$$\frac{1}{N(a,t)}\frac{\partial N}{\partial t} = r(a,t).$$

Therefore

$$\frac{1}{N(a,t)}\frac{\partial N}{\partial a} = -r(a,t) - \mu(a,t)$$

i.e.;

$$\frac{\partial}{\partial a} \log N(a,t) = -r(a,t) - \mu(a,t)$$

as in equation (2.5). The results in (2.6) and (2.8) follow by integrating this equation if $a \leq x \leq a+n$ and if $0 \leq x \leq a$, respectively.

Given the probability of a person dying by age x after having survived to age 'a' is ${}_{x-a}q_a$, we have that ${}_{\infty}q_a = 1$ since he must eventually die. Hence

$$\begin{aligned} N(a) &= N(a)\,.\,{}_{\infty}q_a \\ &= \int_a^\infty N(a)\,{}_{x-a}P_a\ \mu(x)\ dx \\ &= \int_a^\infty N(a)\,{}_{x-a}P_a\ \exp\left[-\int_a^x r(u)du\right]\mu(x)\exp\left[\int_a^x r(u)du\right]dx \end{aligned}$$

Implementing equation (2.8), we have

$$N(a) = \int_a^\infty N(x)\ \mu(x)\ \exp\left[\int_a^x r(u)du\right]dx$$

$$= \int_a^\infty D^*(x) \exp \left[\int_a^x r(u)du \right] dx \quad .... \qquad (2.13)$$

Since

$$\frac{D^*(x)}{N(x)} = \mu(x)$$

For computational purposes, we split the region of integration, $a < x < \infty$, into two parts; namely, from 'a' to 'a+n' and from 'a+n' to infinity. So formula (2.13) becomes,

$$N(a) = \int_a^{a+n} D^*(x) \exp \left[\int_a^x r(u)du \right] dx$$

$$+ \int_{a+n}^\infty D^*(x) \exp \left[\int_a^x r(u)du \right] dx$$

Also splitting the interval $a \leq u \leq x$ in the second part, we have

$$N(a) = \int_a^{a+n} D^*(x) \exp \left[\int_a^x r(u)du \right] dx$$

$$+ \int_{a+n}^\infty D^*(x) \exp \left[\int_a^{a+n} r(u)du + \int_{a+n}^x r(u)du \right] dx$$

$$= \int_a^{a+n} D^*(x) \exp \left[\int_a^x r(u)du \right] dx$$

$$+ \left\{ \int_{a+n}^\infty D^*(x) \exp \left[\int_{a+n}^x r(u)du \right] dx \right\} \left\{ \exp \left[\int_a^{a+n} r(u)du \right] \right\}$$

Using formula (2.13), then

$$N(a) = \int_a^{a+n} D^*(x) \exp \left[\int_a^x r(u)du \right] dx$$

$$+ N(a+n) \exp \left[\int_a^{a+n} r(u)du \right] \quad .... \qquad (2.14)$$

If

$$r(u) = {}_n r_a \text{ for } a \leq u \leq a+n$$

and

$$ {}_nD_a^* = \int_a^{a+n} D^*(x)\,dx $$

then

$$ N(a) = \int_a^{a+n} D^*(x) \exp\left[(x-a)\ {}_nr_a\right] dx $$

$$ + \quad N(a+n) \exp\left[n.\ {}_nr_a\right] $$

By the Mean Value Theorem, there exists a value 'ξ', $a \leq \xi \leq x$, such that

$$ \int_a^{a+n} D^*(x) \exp\left[(x-a).{}_nr_a\right] dx = \int_a^{a+n} D^*(x) \exp\left[\xi.{}_nr_a\right] dx $$

$$ = \left[\int_a^{a+n} D^*(x)\,dx\right] \exp\left[\xi.{}_nr_a\right] $$

Therefore (2.14) becomes

$$ N(a) = {}_nD_a^* \exp\left[\xi.{}_nr_a\right] + N(a+n)\ \cancel{\exp\left[n.{}_nr_a\right] \ldots\ldots (2.15)} $$

Now, for

$$ n = 5 $$

we have

$$ r(u) = {}_5r_a\ , \quad a \leq u \leq a+5 $$

and

$$ \xi \doteq 2.5 $$

Hence

$$ N(a) \doteq {}_5D_a^* \exp\left[2.5\ {}_5r_a\right] + N(a+5) \exp\left[5.\ {}_5r_a\right] \ldots (2.16) $$

for

$$ a = 0, 5, 10, \ldots, A - 5 $$

where A is the lower bound of the open interval.

The formula for the open interval is based on a suggestion by Ansley Coale to Bennett and Horiuchi[6] (1981). The derivation is as follows:

From equation (2.13), we have

$$N(a) = \int_0^\infty D^*(x) \exp \left[\int_a^x r(u)du \right] dx.$$

For the open interval, population above age 'a' is assumed to be stable with $r(u) = r$, say.

Thus

$$N(a) = \int_a^\infty D^*(x) \exp \left[(x-a)r \right] dx \quad \ldots\ldots \qquad (2.17)$$

Letting $y = x-a$, then $dy = dx$.

If $x = a$, $y = 0$

and

if $x = \infty$, $y = \infty$.

Therefore

$$N(a) = \int_0^\infty D^*(a+y) \exp (ry)\, dy$$

$$= \int_0^\infty D^*(a+y)\, e^{ry}\, dy \ldots \qquad (2.18)$$

In taking the first three terms of the Taylor's expansion of e^{ry}, we obtain

$$N(a) \doteq \int_0^\infty (1+ry+r^2\frac{y^2}{2})\, D^*(a+y)\, dy$$

$$= \int_0^\infty D^*(a+y)dy + \int_0^\infty ry\, D^*(a+y)\, dy$$

$$+ \int_0^\infty \frac{r^2}{2} y^2\, D^*(a+y)\, dy$$

Let

$$D^*(a+) = \int_0^\infty D^*(a+y)\, dy$$

and

$$f(a,y) = \frac{D^*(a,y)}{\int_0^\infty D(a,y)dy} = \frac{D^*(a,y)}{D^*(a+)}$$

is a probability density function.

Thus

$$N(a) = D^*(a+)\left[1+\int_0^\infty ry \frac{D^*(a+y)}{D(a+)}dy+\int_0^\infty \frac{r^2}{2} y^2 \frac{D^*(a+y)}{D(a+)}\right]$$

$$= D^*(a+)\left[1+r\int_0^\infty y\ f(a,y)dy+\frac{r^2}{2}\int_0^\infty y^2 f(a,y)dy\right]$$

$$= D^*(a+)\left[1+r\ E(y) + \frac{r^2}{2} E(y^2)\right]$$

$$= D^*(a+)\left[1+r\bar{y} + \frac{r^2}{2} (\bar{y}^2 + \sigma^2)\right]$$

Where $\bar{y}$ and σ^2 are the mean and variance of age at death above 'a', respectively.

It can be proved that

$$\bar{y} = e(a) - r\sigma^2 \quad .... \qquad (2.19)$$

Therefore, by substitution we obtain,

$$N(a) \doteq D^*(a+)\left[1+r(e(a)-r\sigma^2) + \frac{r^2}{2}\left((e(a)-r\sigma^2)^2 + \sigma^2\right)\right]$$

$$= D^*(a+)\left[1+r\ e(a)-r^2\sigma^2 + \frac{r^2}{2}\left(e^2(a)-2r\ e(a)\sigma^2+r^2(\sigma^2)^2\right) + \sigma^2\right]$$

$$= D^*(a+)\left[1+ re(a)+\frac{r^2}{2} e^2(a)-\frac{r^2}{2} \sigma^2\right]$$

$$\doteqdot D^*(a+) \{ \exp [re(a) - r^2 \frac{\sigma^2}{2}]\}$$

σ^2 is well approximated by

$$\sigma^2 \doteqdot \frac{e^2(a)}{3}, \quad \text{for} \quad a \geq 10$$

for a wide array of existing life tables.

Hence, it follows that

$$N(a) \doteqdot D^*(a+) \{\exp[re(a)] - \frac{[re(a)]^2}{6}\} \ldots \qquad (2.20)$$

Given an approximate level of mortality, we can estimate e(a) from a model life table.

2.3 METHOD I: ESTIMATION OF THE COMPLETENESS OF DEATH REGISTRATION.

Suppose that the completeness of death registration is constant at age 'a' and above, then

$$D^*(x) = k\ D(x) \text{ for all } x \geq a \qquad \ldots (2.21)$$

Where D(x) is the number of registered deaths to persons aged x, D*(x) is the true number of deaths experienced by persons aged x in the current population and k is the inverse of the completeness of death registration.

By substituting D*(x) by k D(x) as given in equation (2.13), we obtain

$$N(a) = k \int_a^\infty D(x) \exp[-\int_a^x r(u)du]dx \quad \ldots \qquad (2.22)$$

Now if we define

$$\hat{N}(a) = \int_a^\infty D(x) \exp\left(\int_a^x r(u)\,du\right) dx \quad \ldots. \ (2.23)$$

then

$$N(a) = K\,\hat{N}(a)$$

Thus

$$C = \frac{1}{k} = \frac{\hat{N}(a)}{N(a)} \quad \ldots\ldots\ldots\ldots \quad (2.24)$$

where C is the completeness of death registration. If k = 1 then C = 1 which implies that the completeness of death registration is 100%; otherwise k is not equal to unity.

More robust measures of completeness have been suggested, such as that derived from cumulating $\hat{N}(a)$ and N(a). Cumulation would tend to absorb some of the distortions resulting from age misreporting and differential registration and enumeration by age.

For practical purposes, we have shown that

$$N(a) \doteq N(a+5) \exp\left[5 \cdot {}_5r_a\right] + {}_5D_a^{*} \exp\left[2.5\ {}_5r_a\right]$$

Hence

$$\hat{N}(a) \doteq \hat{N}(a+5) \exp\left[5 \cdot {}_5r_a\right] + {}_5D_a \exp\left[2.5\,{}_5r_a\right] \ldots. (2.25)$$

For the open interval

$$N(A) \doteq D^{*}(A+) \{\exp\left[r(A+)\ e(A)\right] - \left[\frac{r(A+)e(A)}{6}\right]^{2}\}$$

Hence

$$\hat{N}(A) \doteq D(A+) \{\exp\left[r(A+)\ e(A)\right] - \left[\frac{r(A+)e(A)}{6}\right]^{2}\} \qquad \ldots\ldots(2.26)$$

After obtaining $\hat{N}(A)$, then we can determine or generate all other $\hat{N}(a)$'s for a = 0, 5, 10, ..., A-5. Then the values of ${}_5\hat{N}_a$ can be approximated by the formula

$${}_5\hat{N}_a = 2.5 \quad \hat{N}(a) + \hat{N}(a+5) \qquad \ldots\ldots \qquad (2.27)$$

2.4 METHOD II: LIFE TABLE CONSTRUCTION FROM INCOMPLETE DEATH REGISTRATION DATA.

Apart from the formulae given in section 2.3 for determining the completeness of death registration, from equation (2.6) we have

$${}_nP_a = \frac{N(a+n)}{N(a)} \exp\left[\int_a^{a+n} r(u)du\right]$$

where as defined above ${}_nP_a$ is the probability of survival from age a to age a+n. Given the assumption that completeness of death registration does not vary with age, then

$${}_nP_a = \frac{\hat{N}(a+n)}{\hat{N}(a)} \exp\left[\int_a^{a+n} r(u)du\right] \qquad \ldots\ldots (2.28).$$

The other life table functions can be straightforwardly derived from the ${}_nP_a$'s. Thus given the number of registered deaths by age and a set of age specific growth rates, a life table can be constructed for the population under study.

To estimate $\hat{N}(a+n)$ or $\hat{N}(a)$ values we use equation (2.25). For the open ended interval we use equation (2.26).

As stated earlier, e(A) can be estimated by taking an approximate level of mortality.

Bennett and Horiuchi[7] (1982) however suggested some procedure which takes advantage of the relationship observed in the Coale - Demeny[8] (1982) model life tables between the age distribution of deaths and the expectation of life at a given age in the estimation of e(A).

If D(a) is number of registered deaths at age a and $\mu(a)$ is the instantaneous death rate at age a, then

$$\begin{aligned} D(a) &= N(a)\,\mu(a) \\ &= N(o)\exp\left[-\int_o^a r(x)\,dx\right] P(a)\,\mu(a) \\ &= N(o)\exp\left[-\int_o^a r(x)\,dx\right] d(a) \quad \ldots\ldots (2.29) \end{aligned}$$

where

$$d(a) = P(a)\ \mu(a)$$

$$= \text{deaths at age a in the life}$$

table prevailing at time t (with radix one).

Now let w(a) be the proportionate age distribution (the frequency distribution of ages) of deaths, then

$$w(a) = \frac{D(a)}{\int_0^\infty D(a)\ da}$$

$$= \frac{N(a)\ \mu(a)}{\int_0^\infty N(a)\ \mu(a)\ da}$$

$$= \frac{d(a)\ \exp\left[-\int_0^a r(x)\right] dx}{\int_0^\infty d(a) \exp\left[-\int_0^a r(x) dx\right] da} \quad \ldots\ldots \quad (2.30)$$

From

$$D(a) = N(o)\ \exp\left[-\int_0^a r(x) dx\right] da$$

we get

$$N(o)\ d(a) = D(a)\ \exp\left[\int_0^a r(x)\right] dx$$

Therefore

$$\int_0^\infty N(o)\ d(a)\ da = \int_0^\infty D(a)\ \exp\left[\int_0^a r(x) dx\right] da$$

i.e.,

$$N(o) \int_0^\infty d(a) da = \int_0^\infty D(a) \exp\left[\int_0^a r(x) dx\right] da.$$

But

$$\int_0^\infty d(a)\,da = 1$$

Therefore

$$N(o) = \int_0^\infty D(a)\,\exp\left[\int_0^a r(x)dx\right]da$$

So

$$d(a) = \frac{d(a)}{\int_0^\infty d(a)\,da}$$

$$= \frac{D(a)\exp\left[\int_0^a r(x)\right]dx}{\int_0^\infty D(a)\exp\left[\int_0^a r(x)dx\right]da}$$

$$= \frac{D(a)\ \exp\left[\int_0^a r(x)dx\right]}{N(o)} \quad \ldots. \quad (2.31)$$

which implies that

$$\int_0^a d(a)da = \frac{\int_0^\infty D(a)\exp\left[\int_0^a r(x)\ dx\right]da}{N(o)} = 1$$

Now,

$\int_0^\infty D(a)\exp\left[\int_0^a r(x)\ dx\right]da \Big/ N(o)$ will equal to unity if deaths are completely registered. If they are registered with completeness C at all ages, then the value will equal C. Therefore, its value provides a direct estimate of registration completeness.

That is $\dfrac{\int_0^\infty D(a)\exp\left[\int_0^a r(x)dx\right]da}{N(o)} = C$

Thus

$$\int_0^\infty \frac{D(a)}{C\,N(o)} \exp\left[\int_0^a r(x)\,dx\right] da = 1$$

So

$$d(a) = \frac{D(a)}{C.N(o)} \exp\left[\int_0^a r(x)\,dx\right] \quad \ldots (2.32)$$

Let N(o) = B, annual number of births,

then

$$d(a) = \frac{D(a)}{C.B} \exp\left[\int_0^a r(x)\,dx\right] \quad \ldots (2.33)$$

The discrete analogue to this equation is

$${}_5d_a = \frac{1}{C.B}\,{}_5D_a \exp\left[\sum_{x=0}^{a-5} {}_5r_x + 2.5\,{}_5r_a\right] \quad \ldots (2.34)$$

Within each family (West, North, East or South) of the model life table system, there exist a one-to-one relationship between the ratio of adolescent and younger adult deaths (ages 10 to 40) to older adult deaths (ages 40 to 60), and the life expectancy at any age x, for x = 60, ..., 95 (Coale and Demeny,[9] 1982).

Thus when the values of ${}_5d_a$ are summed to form the ratio ${}_{30}d_{10}/{}_{20}d_{40}$, it is not necessary to know C and B since they appear in both the numerator and denominator and cancel each other out.

Once we compute the ratio, we refer to the appropriate family of model life tables for the corresponding e(x) value, which may be approximated by interpolation.

Table A.1 in the appendix displays the ratios of ${}_{30}d_{10}/{}_{20}d_{40}$ and the corresponding values of e(75) through e(95) which are associated with the Coale - Demeny West model life tables for males and females at many different levels of mortality. It should be emphasized that if one is limiting the estimation of e(x) to ages above 75 or so (as in our case), then the impact of an incorrect choice of e(x) will be minimal in the estimation of life expectancy at birth.

Using equations (2.25) and (2.26) we can generate all values of $\hat{N}(a)$, for $a = o, 5, \ldots, A - 5$ and A. After computing these values, it is a simple matter to derive five-year survival probabilities by using

$$ {}_5P_a = \frac{\hat{N}(a+5)}{\hat{N}(a)} \exp\left[5 \cdot {}_5r_a\right], $$

which is the five year discrete version of equation (2.6).

The other life table functions are derived from the sequence of ${}_5P_a$'s by the following equations

$$ \frac{\ell_{a+5}}{\ell_a} = {}_5P_a \quad \ldots. \qquad (2.35) $$

$$ {}_5d_a = \ell_a \left(1 - {}_5P_a\right) \quad \ldots\ldots \qquad (2.36) $$

$$ {}_5L_a = \frac{5}{2} \left(\ell_a + \ell_{a+5} \right) \quad \ldots\ldots \quad (2.37) $$

$$ T_a = \sum_{y=a}^{\infty} {}_5L_y \quad \ldots\ldots\ldots\ldots\ldots \quad (2.38) $$

and

$$ e_a = \frac{T_a}{\ell_a} \quad \ldots\ldots\ldots\ldots \quad (2.39) $$

* In the derivation of equation (2.16) from which equation (2.25) is obtained, at one point, we arrive at the following equality:

$$ \int_a^{a+5} D^*(x) \cdot \exp\left[\bar{Z} \cdot {}_5r_a\right] dx = {}_5D_a^* \exp\left[\bar{Z} \cdot {}_5r_a\right] $$

We assume Z to equal 2.5, though in an age group where the age distribution of deaths is declining rapidly, this is a poor assumption and will contribute to a biased estimate of N(a) at the older ages. A correction factor, ${}_5\gamma_x$, is therefore developed which will compensate for the error due to this assumption. Equation (2.25) is thus adjusted to be

$$ \hat{N}(a) = \hat{N}(a+5) \exp\left[\bar{5}\ {}_5r_a\right] + {}_5\gamma_a\ {}_5D_a \exp\left[2.5\,{}_5r_a\right] \qquad \text{for } a \geq 60 $$

where ${}_5\gamma_x$ is estimated by the formula

$$ {}_5\gamma_x = 1.00 - 2.26\,{}_5r_x\ {}_5M_x + .218\ {}_5r_x - .826\ {}_5r_x^2 $$

and ${}_5M_x$ is the observed age specific death rate.

2.5 METHOD III: INTERCENSAL METHOD OF MORTALITY ESTIMATION.

Preston[10] (1981) proposed a method for the estimation of adult mortality to which a population has been subject to during a given intercensal period from the age distributions produced by two consecutive censuses. As any other method that estimates mortality on the basis of intercensal comparisons, Preston's method requires that the population be closed (that is not subject to migration) and that the completeness of coverage attained by each of the censuses being compared be the same. However, the population under consideration need not be stable.

Preston's method is based on the validity of equation (2.6)

i.e.

$$N(a+n) = N(a)\ {}_{n}P_{a} \exp\left[-\int_{a}^{a+n} r(x)dx\right].$$

Changing the dummy variables to a+n = y and x = a, we have

$$N(y) = N(x)\ {}_{y-x}P_{x} \exp\left[-\int_{x}^{y} r(a)da\right], \text{ and}$$

since

$$ {}_{y-x}P_{x} = \frac{\ell_{(y)}}{\ell_{(x)}}$$

we have

$$N(y) = N(x)\left[\frac{\ell_{(y)}}{\ell_{(x)}}\right]\exp\left[-\int_{x}^{y} r(a)da\right] \quad \ldots\ldots\ldots \quad (2.40)$$

Thus if N(x), N(y), and the set of r(u) values for u between x and y are all known, then the survivorship probability $\ell(y)/\ell(x)$ can be estimated from equation (2.40). In order to introduce a certain amount of smoothing, Preston proposed the estimation of expectation of life at each age x, using extensive cumulation both of the reported population and of the observed age specific growth rates.

By definition

$$\overset{o}{e}_x = \frac{T_x}{\ell_x}$$

$$= \frac{1}{\ell_x}\int_0^\infty \ell_{(x+t)}\,dt$$

$$= \int_0^\infty \frac{\ell_{(x+t)}}{\ell_{(x)}}\,dt$$

In particular

$$\overset{o}{e}_o = \int_0^\infty {}_tP_o\,dt$$

$$= \int_0^\infty P(t)\,dt$$

From equation (2.40) we have,

$${}_{y-x}P_x = \frac{N(y)}{N(x)}\exp\left[\int_x^y r(a)da\right]$$

Therefore

$$\overset{o}{e}_x = \int_0^\infty {}_{y-x}P_x\,dy$$

$$= \int_0^\infty \frac{N(y)}{N(x)} \exp\left[\int_x^y r(a)da\right] dy \quad \ldots (2.41)$$

In discrete terms with five-year age interval, we then have

$$e_x^o = \frac{\sum_{y=x}^{\infty} {}_5N_y \exp\left[5. \sum_{a=x}^{y-5} {}_5r_a + 2.5 \; {}_5r_y\right]}{N(x)} \quad \ldots (2.42)$$

where ${}_5N_y$ is taken as the mean of the two censuses age distributions, ${}_5r_y$ is the intercensal growth rates of age group y to y+4 given by

$$ {}_5r_y = \frac{1}{t_2-t_1} \; \ell n \left[\frac{{}_5N_y \; (t_2)}{{}_5N_y \; (t_1)}\right] \quad \ldots\ldots (2.43)$$

where t_1 and t_2 are the periods when the censuses were conducted, and N(x) is the mid-period number of persons aged x, estimated by

$$N(x) = \frac{{}_5N_x + {}_5N_{x-5}}{10} \quad \ldots\ldots. (2.44)$$

However a preferable procedure is to derive N(x) in a fashion analogous to the derivation of the numerator in equation (2.42),

i.e.;

$$N(x) = \frac{{}_5N_x \exp\left[-2.5 \; {}_5r_{x-5}\right] + {}_5N_x \exp\left[2.5 \; {}_5r_x\right]}{10} \quad \ldots\ldots. (2.45)$$

From equation (2.42) it is noted that the observed growth rate of the open interval is used for the purposes of estimation. Hill and Zlotnik[11] (1982) however argued that since age reporting at older ages is, if anything, less reliable than at younger ones, it is not advisable to use the observed growth rate of the open interval for the purposes of estimation. Because of this, they suggested that the contribution, $\rho(A)$, of the growth rate of the uppermost age group in mortality estimation be calculated on the basis of other, more reliable evidence, such as the growth rate of the population over 10 ($r(10+)$) and the ratio of the population over 45 to the population over age 10 at the middle of the intercensal period ($N(45+) / N(10+)$). Using simulated stable populations and least - squares regression; they arrived at the following equation relating $\rho(A)$ to the quantities just cited,

$$\rho(A) = a(A) + b(A)\, r(10+) + C(A)\, \ell n\, (N(45+)/N(10+)) \quad \ldots\ldots (2.46)$$

with the values of the coefficients a(A), b(A) and C(A) as listed in table A.2 in the appendix.

Define R(x) by

$$R(x) = 2.5\; {}_5r_x + 5.0 \sum_{y=o}^{x-5} {}_5r_y \quad \ldots\ldots (2.47)$$

Then for the open interval,

$$R(A) = \rho(A) + 5.0 \sum_{y=0}^{A-5} {}_5r_y \quad \ldots\ldots\ldots \quad (2.48)$$

Once the R(x) values are available, they are used to transform the observed mid-period populations into Pseudo ${}_5L_x$ values denoted by ${}_5L^*_x$. Thus if ${}_5N_x$ is the mid-period population in age group x to x+4, that is

$$ {}_5N_x = .5 \left[{}_5N_x(t_1) + {}_5N_x(t_2) \right] \quad \ldots\ldots \quad (2.49)$$

then

$$ {}_5L^*_x = {}_5N_x . \exp \; R(x) \quad \ldots\ldots\ldots \quad (2.50)$$

and

$$ {}_\infty L^*_A = {}_\infty N_A . \exp R(x) \quad \ldots\ldots\ldots \quad (2.51)$$

The term "Pseudo" is used here to remind the reader that although the ${}_5L^*_x$ values calculated according to equation (2.50) can be used to estimate expectation of life, they cannot, in general, be manipulated as the usual life table ${}_5L_x$'s because, among other things, their radix is not known.

Pseudo Tx* and ℓx* values are given by

$$\ell_x^* = ({}_5L^*_{x-5} + {}_5L^*_x / 10 \quad \ldots\ldots\ldots \quad (2.52)$$

and

$$T_x^* = \sum_{y=x}^{A-5} {}_5L_y^* + {}_\infty L_A^* \quad \ldots\ldots\ldots \quad (2.53)$$

Finally the life expectancy estimates that are analogous to those of the life table are given as

$$e_x = T_x^* / \ell_x^* \quad \ldots\ldots\ldots \quad (2.54)$$

Note that the behaviour of the ${}_5L_x^*$ values does not by itself invalidate the set of the life expectancy estimates that are derived from them. Further note that equation (2.54) is equivalent to equation (2.42), with both numerator and denominator including as common factor

$$R(x) - 2.5\ {}_5r_x = 5.0 \sum_{y=0}^{x-5} {}_5r_y \quad \ldots\ldots\ldots \quad (2.55)$$

2.6 METHOD IV: LIFE TABLE CONSTRUCTION BY CAUSES OF DEATH

As a country passes through various stages of development, it also experiences something of an epidemiological transition. The cause of death structure of a population changes. Hence differences in the relative contributions of particular causes of death to the overall mortality structure of a population are important to study.

For this, two approaches, namely, the single and multiple decrement approaches have been used in this study. In addition to the standard actuarial notations used above, superscripts are used to indicate death from a certain cause. For example ${}_nM_x^i$ is the observed death rate between ages x and x+n from cause i. ${}_nM_x^{-i}$ is the observed death rate between ages x and x+n when cause i is eliminated.

(a) SINGLE DECREMENT APPROACH:

In this method, cause of death analysis is made under the assumption that death results from one and only one cause i and that all the others are absent. Further, the assumption is made that deaths from all these causes are independent of each other.

If the above be the case, then the forces of mortality $\mu^1(x), \mu^2(x), \ldots \mu^i(x) \ldots \mu^k(x)$ for k causes of death are additive. i.e.

$$\mu(x) = \sum_{i=1}^{k} \mu^i(x) \qquad \ldots\ldots\ldots \quad (2.56)$$

$\mu(x)$ is defined as the limiting value of the death rate when the age interval becomes very short. Since the life table deaths in the age interval x to $x+\Delta x$ are $\ell(x) - \ell(x+\Delta x)$, and the exposure is $\ell(x)\Delta x$, we have

$$\mu(x) = \lim_{\Delta x \to 0} \frac{\ell(x) - \ell(x+\Delta x)}{\ell(x)\ \Delta x}$$

$$= -d \frac{\ell(x)}{\ell(x)\ dx}$$

$$\therefore\ \mu(x) = -d \frac{\log \ell(x)}{dx} \qquad \ldots\ldots(2.57)$$

Solving the differential equation that defines $\mu(x)$, we have

$$\log\left[\frac{\ell(x+t)}{l(x)}\right] = -\int_0^t \mu(x+r)\,dr \qquad \ldots\ldots.\ (2.58)$$

The probability of living at least an additional n years after one has attained age x is

$$\frac{\ell_{x+n}}{\ell_x} = e^{-\int_0^n \mu(x+r)\,dr} \qquad \ldots\ldots. \quad (2.59)$$

Further, if ℓ^i_x is the number of survivors at age x with only the i^{th} cause acting (when all causes but the i^{th} are eliminated) and $\ell^i x+n$ is the number of survivors an additional n years after age x with only the i^{th} cause acting, then from expression (2.59) we have

$$-\ln \frac{\ell^i x+n}{\ell^i x} = \int_0^n \mu^i(x+t)\ dt$$

$$= \left[\frac{\int_0^n \mu^i(x+t)\ dt}{\int_0^n \mu\ (x+t)\ dt}\right] \int_0^n \mu(x+t)\ dt$$

$$= R \int_0^n \mu(x+t)\ dt, \text{ say,}$$

and on multiplying by -1 and taking exponentials of both sides, we have

$$\frac{\ell^i_{x+n}}{\ell^i_x} = \left[\frac{\ell_{x+n}}{\ell_x}\right]^R$$

where $R = \dfrac{{}_nM^i_x}{{}_nM_x}$

$$\therefore \frac{\ell^i_{x+n}}{\ell^i_x} = \left[\frac{\ell_{x+n}}{\ell_x}\right]^{\frac{{}_nM^i_x}{{}_nM_x}} \quad \ldots\ldots\ldots \quad (2.60)$$

That is, the probability of surviving an additional n years after attaining exact age x with only the i^{th} cause acting, ${}_nP^i_x$, is given by

$$ {}_nP^i_x = \left[\frac{\ell_{x+n}}{\ell_x}\right]^{\frac{{}_nM^i_x}{{}_nM_x}} \quad \ldots\ldots\ldots \quad (2.61)$$

Where ${}_nM^i_x$ is the observed death rate from cause i, i.e.;

$$ {}_nM^i_x = \frac{{}_nD^i_x}{{}_nN_x}$$

Where ${}_nD^i_x$ is number of deaths in the age interval x to x+n with only the i^{th} cause acting and ${}_nN_x$ is the registered population in the age group x to x+n.

Similarly

$$ {}_nM_x = \frac{{}_nD_x}{{}_nN_x}$$

Where ${}_nD_x$ is the total number of deaths (from all causes combined) in the age group x to x+n.

Consequently, the survival probability, ${}_np^i_x$, when all causes but i are eliminated is given by the expression

$$ {}_nP^i_x = \frac{\ell^i_{x+n}}{\ell^i_x} = \left[\frac{\ell_{x+n}}{\ell_x}\right]^{\frac{{}_nM^i_x}{{}_nM_x}}. $$

$$ = \left[\frac{\ell_{x+n}}{\ell_x}\right]^{\frac{{}_nD^i_x}{{}_nN_x} \Big/ \frac{{}_nD_x}{{}_nN_x}} $$

$$ = \left[\frac{\ell_{x+n}}{\ell_x}\right]^{\frac{{}_nD^i_x}{{}_nD_x}} $$

$$ \therefore \quad {}_nP^i_x = \left[\frac{\ell_{x+n}}{\ell_x}\right]^{\frac{{}_nD^i_x}{{}_nD_x}} \quad \ldots\ldots (2.62) $$

Note that if the completeness of death registration does not vary with cause of death, i.e. it is constant, then we need not make correction for the completeness of death registration in the estimation of the ${}_np^i_x$ values since it will appear in both numerator and denominator of the ratio ${}_nD^i_x/{}_nD_x$ and will cancel each other out.

Conversely, if ${}_nP^{-i}_x$ is the survival probability with all causes present except the i^{th} cause (when only cause i is eliminated), $\bar{\ell}_x^i$ and $\bar{\ell}_{x+n}^i$ are the corresponding survivors at ages x and x+n respectively,

then

$$ {}_n\bar{P}_x^i = \frac{\bar{\ell}_{x+n}^i}{\bar{\ell}_x^i} = \left[\frac{\ell x+n}{\ell x}\right]^{\frac{{}_nD_x^{-i}}{{}_nD_x}} \quad \ldots . \ (2.63)$$

Where ${}_nD_x^{-i}$ is number of deaths in the age group x to x+n when only the i^{th} cause is eliminated.

Once the survival probabilities are calculated, the other life table functions can easily be computed.

(b) MULTIPLE DECREMENT APPROACH:

The critical assumption here is that no cause of death occurs completely in isolation from other causes. This is a more realistic assumption since most deaths result from a chain of preceeding conditions.

This means that life table deaths ${}_nd_x^i$ from cause i have to be assumed to have resulted from all other causes, and hence be distributed among these causes.

If all real life table deaths are represented by ${}_nD_x$, and the observed number dying of a given cause i is ${}_nD_x^i$ and the life table deaths are ${}_nd_x$, then the life table number dying of cause i, ${}_nd_x^i$ is given by

$$ {}_nd_x^i = \frac{{}_nD_x^i}{{}_nD_x} \cdot {}_nd_x \qquad \ldots\ldots \quad (2.64) $$

Equation (2.64) is computationally sufficient. However the terms used in it can be elaborated as follows:

$$ \text{i)} \quad {}_nd_x^i = \int_0^n \ell(x+t)\,\mu^i(x+t)\,dt. $$

This represents the number of deaths from cause i for a finite interval.

$$ \text{ii)} \quad \frac{{}_nD_x^i}{{}_nD_x} = \frac{\int_0^n e^{-rt}\,\ell(x+t)\,\mu^i(x+t)\,dt}{\int_0^n e^{-rt}\,\ell(x+t)\,\mu(x+t)\,dt} \quad \ldots .(2.65) $$

The derivation of the death probabilities from various causes, in this study follows the simple

$$ \frac{{}_nD_x^i}{{}_nD_x} \cdot {}_nd_x \text{ formula,} $$

and does not integrate the elaborations suggested by Keyfitz[12] (1977).

Finally note that as in Method IV (a), under the assumption that completeness of death registration does not vary with age and cause of death, no correction for underregistration need be made in the application of equation (2.65).

Once life tables have been constructed from incomplete death registration data by Method II as defined above, it becomes a matter of applying the formulae developed in Method IV (a and b) to generate life tables by cause(s) of death. Life table functions of particular interest are the survival and death probabilities and the expectation of life at various age groups or ages. $e^{i}(A)$ is estimated by using the ${}_{30}d^{i}_{10}$ / ${}_{20}d^{i}_{40}$ ratio as explained in Method II above. Similarly $e^{-i}(A)$ is estimated by using the ratio ${}_{30}d^{-i}_{10}$ / ${}_{20}d^{-i}_{40}$.

Where A is the lower bound of the open ended interval.

Note that in Method IV (a), once the ${}_{n}p^{i}_{x}$ values have been estimated, then the ${}_{n}Q^{i}_{x}$ values, (death probabilities), ${}_{n}d^{i}_{x}$ values (life table deaths) and the ℓ^{i}_{x} values are easily computed. For the computation of ${}_{n}L^{i}_{x}$, T^{i}_{x} and e^{i}_{x} values, we first estimate $e^{i}(A)$ as described above.

For Method IV (b). Once we compute the ${}_{n}d^{i}_{x}$ values, we proceed to compute all the other life table functions. Here we also estimate $e^{i}(A)$ or $e^{-i}(A)$ before we compute the corresponding ${}_{n}L_{x}$, T_{x} and e_{x} values.*

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CHAPTER III

ESTIMATION OF ADULT MORTALITY USING AGE SPECIFIC GROWTH RATE TECHNIQUES

3.1 INTRODUCTION

In this chapter we intend to study adult mortality in Kenya using the age specific growth rate techniques described in Chapter II. Specifically, we would like to

i) evaluate the completeness of death registration in 1979 as reported by the Registrar General's Office relative to the population as enumerated in 1979;

ii) construct life tables for Kenya using the 1969 and 1979 population censuses along with the information of number of deaths registered in 1979 (deaths which occurred in 1979 and were reported in 1979);

and iii) construct life tables for Kenya using only the two successive censuses of 1969 and 1979.

For this study, we therefore need the 1969 and 1979 populations and the number of deaths in 1979 classified by age and sex as shown in table 3.1.1 and 3.1.2 below.

At this juncture, we would like to point out that the 1979 census age distributions have been adjusted for the fact that a certain number of those enumerated did not declare their age (those in the "Age Not Stated" category were distributed according to the age distribution of those whose age was recorded). i.e. Suppose the per cent distribution of the unknown age is the same as those of known age, then the correction or adjustment factor f is given by the formula:

$$f = \frac{P_u + \sum_{a=o}^{\infty} P_a}{\sum_{a=o}^{\infty} P_a} \quad \ldots\ldots\ldots \quad (3.1.1)$$

Where P_a represents the number reported at each age and P_u is the number whose age was not reported (unknown).

Therefore the adjusted value at age a $(a = o, \ldots \infty)$, $P_a{}^*$ is

$$P_a{}^* = \left[\frac{P_u + \sum_{a=o}^{\infty} P_a}{\sum_{a=o}^{\infty} P_a}\right] P_a \quad \ldots\ldots \quad (3.1.2)$$

$$= f\,P_a.$$

We would also like to note that since the censuses considered in this study took place on August 25th/26th, 1969 and August 25th/26th, 1979 respectively, the length of the intercensal interval used in the calculation of the age specific growth rates is 10 years.

That is, if $_5r_a$ is the age specific growth rate between age 'a' and age 'a+5', $_5N_a$ (1969) and $_5N_a$ (1979) are the enumerated populations in the age group a to a+5 in 1969 and 1979 respectively, then

$$_5r_a = \frac{1}{10} \ln \left[\frac{_5N_a\ (1979)}{_5N_a\ (1969)} \right] \quad \ldots . \quad (3.1.3)$$

Table 3.1.1: Kenya Censuses Data (1969 and 1979) and Number of registered deaths (current) in 1979: Males.

Age Group	1969 Population	1979 Population	1979 Adjusted	Age Specific Growth Rate ($_5r_a$)	No. of Regis'd Deaths 1979 $_5D_a$
0 - 4	1 058 012	1 422 021	1 424 954	.02977	7739
5 - 9	916 599	1 247 091	1 249 662	.031	803
10 - 14	714 707	1 050 932	1 053 099	.03876	445
15 - 19	560 152	854 123	855 884	.04239	427
20 - 24	428 015	641 401	642 723	.04066	452
25 - 29	349 594	514 451	515 512	.03884	566
30 - 34	280 948	405 385	406 221	.03687	558
35 - 39	252 136	290 227	290 825	.01428	578
40 - 44	193 936	261 480	262 019	.03009	629
45 - 49	172 508	218 914	219 365	.02403	638
50 - 54	132 466	182 908	183 285	.03247	763
55 - 59	114 669	140 777	141 067	.02072	675
60 - 64	102 466	107 710	107 932	.00520	902
65 - 69	74 611	99 906	100 112	.02940	781
70 - 74	48 363	66 369	66 506	.03186	869
75 +	83 109	87 766	87 947	.00566	2576
NOT STATED		15 652			

Table 3.1.2: Kenya Censuses Data (1969 and 1979) and Number of registered Deaths (Current) 1979: Females.

Age Group	1969 Population	1979 Population	1979 Adjusted	Age Specific Growth Rate $_5r_a$	No. of Regis'd Death 1979 $_5D_a$
0 - 4	1 046 380	1 421 385	1 423 936	.03081	6939
5 - 9	893 359	1 244 749	1 246 983	.03335	702
10 - 14	663 808	1 023 839	1 025 677	.04351	357
15 - 19	544 847	887 722	889 316	.04899	340
20 - 24	450 096	686 003	687 234	.04232	341
25 - 29	411 245	541 261	542 233	.02765	352
30 - 34	299 241	412 691	413 432	.03232	316
35 - 39	264 819	325 367	325 951	.02077	338
40 - 44	201 936	273 702	274 193	.03059	269
45 - 49	163 852	221 965	222 363	.03053	304
50 - 54	139 072	191 022	191 365	.03192	350
55 - 59	102 235	134 534	134 776	.02763	277
60 - 64	94 508	109 518	109 715	.01492	482
65 - 69	63 307	83 221	83 370	.02753	368
70 - 74	45 987	62 539	62 651	.03092	413
75 +	75 632	86 597	86 752	.01372	1576
NOT-STATED		13 833			

3.2 ESTIMATING THE COMPLETENESS OF DEATH REGISTRATION

Although developing countries often possess vital registration systems, the level of coverage they achieve is not always satisfactory. Thus age-specific mortality rates calculated directly from the registered deaths usually underestimate mortality. A method of adjustment that would transform the observed rates into better estimates of mortality conditions is therefore highly desirable.

Over the years demographers have proposed several such methods of adjustment. Perhaps the best known among them is the Growth Balance Equation Method proposed by Brass[1] (1975). More recently, Preston and colleagues (Preston et al;[2] 1980) have suggested a similar method which, although still based on the assumption of stability, provides greater capabilities in terms of the evaluation of the input data and the assessment of results.

In this thesis, we shall use the Bennett and Horiuchi[3] (1981) technique which is essentially a modification of the Preston et al.[4] (1980) technique whereby the assumption of stability is no longer necessary.

to study the completeness of registered deaths in Kenya in 1979 relative to the population of Kenya by age and sex as enumerated in 1979.

Measures of completeness have been derived from cumulating $\hat{N}(a)$ and $N(a)$. Cumulation would tend to absorb some of the distortions resulting from age misreporting and differential registration and enumeration by age. And the formulae which have been used to determine the completeness have been derived in Chapter II and described in Method I.

Essentially, if k is the degree of completeness of death registration; then

$$k = \frac{\hat{N}(a)}{N(a)} \quad \ldots\ldots \quad (3.2.1)$$

for all values of a (a=o, 5, ... A-5 and A).

Where

$$\hat{N}(a) = \hat{N}(a+5) \exp[5.\ {}_5r_a] + {}_5D_a \exp[2.5\ {}_5r_a] \quad \ldots\ldots \quad (3.2.2)$$

for

$a=o, 5, \ldots, A-5,$

and

$$\hat{N}(A) = D(A+)[\exp(r(A+)e(A))-(\{r(A+)e(A)\}^2/6)] \quad \ldots\ldots \quad (3.2.3)$$

Where A is the lower bound of the open interval.

Once the age specific growth rates, ${}_5r_a$ (a=o, 5, ... A-5) and r(A+) have been calculated and e(A) is determined where r(A+) is the growth rate of the open interval and e(A) is the life expectancy at the beginning of the open interval, the Bennett - Horiuchi[5] (1981) technique of estimating the completeness of death registration can be summarized in the following steps:

Step-One

Compute $\hat{N}(A)$ using equation (3.2.3).

Step-Two

By iterating downward the age distribution, compute $\hat{N}(a)$ for a=o, 5, ... A - 5 using equation (3.2.2)

Step-Three

Compute the estimated population, ${}_5N_a$, in the age a to a+5 where

$$ {}_5\hat{N}_a = 2.5 \left[\hat{N}(a) + \hat{N}(a+5)\right] \quad ..... \quad (3.2.4)$$

Estimates of the completeness of death registration can then be derived as the median of a series of ${}_{10}\hat{N}_{a-5}$ (the estimated number of people between ages a-5 and a+5) divided by the corresponding figures in the observed population.

Where,

$$ {}_{10}\hat{N}_{a-5} = {}_5\hat{N}_{a-5} + {}_5\hat{N}_a \quad .... \quad (3.2.5).$$

Now, we realize that in Step One, we need the value of e(A) in order to estimate N(A) using equation (3.2.3). But in most developing countries (Kenya included), the value of e(A) can only be approximated. For this reason, the alternative method of estimating N(A) proposed by Hill and Zlotnik[6] (1982) which does not need the value of e(A) has also been employed in order to study if the method of estimation of N(A) affects the completeness of death registration.

The Hill and Zlotnik method of estimating N(A) lies on the assumption that if a population above age A "truncation age" is stable, then using stable populations generated from the Coale- Demeny mortality models, there exist a value of Z(A) such that

$$\hat{N}(A) = D(A+) \{ \exp (r(A+)\ Z(A))\} \ldots (3.2.6)$$

Where Z(A) is approximated by the equation

$$Z(A) = a(A) + b(A)r + C(A) \exp \{D(45+)/ D(10+)\} \ldots (3.2.7)$$

Where r = r(A+) is the stable growth rate at age A and above, D(45+) / D(10+) is the ratio of the recorded deaths over age 45 to the recorded deaths over age 10 and a(A), b(A) and C(A) are coefficients obtained by fitting equation (3.2.7) separately to stable populations generated by each of the families of regional model life tables. Table A.3 in the appendix shows the coefficients estimated using the "West" family of regional model life tables.

Once Z(A) is approximated, $\hat{N}(A)$ is estimated by equation (3.2.6). Then all the other $\hat{N}(A)$ (a=o, 5, ... A - 5) values are obtained using equation (3.2.2). Hence the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios are obtained by following the steps outlined above.

Results obtained by the application of this technique referred to as Method I in Chapter II in the study of the completeness of death registration in Kenya in 1979 relative to the population of Kenya by age and sex as enumerated in 1979 are shown in tables 3.2.1 to 3.2.10 for males and tables 3.2.11 to 3.2.19 for females.

Tables 3.2.1 to 3.2.4 show the results for the estimated completeness for males with 60 years as the "truncation age". Different values of e(60) have been used in the estimation of N(60) by equation (3.2.3) i.e.

$$\hat{N}(60) = D(60+) \{\exp[r(60+)\, e(60)] - ([r(60+)e(60)]^2/6)\}$$

Different values of e(60) have been used because the exact level of mortality in Kenya as in most developing countries is not known. The values of e(60) used for males are 14.6 years, 15 years and 13.9 years.

The choice of the e(60) values is however not arbitrarily done. The value of e(60) = 14.6 years was obtained from the 1979 Kenya model life tables[7] by assuming that the model life tables are accurate and correct and Table 3.2.1 shows the estimates of the completeness of death registration when e(60) = 14.6 years was used as an input in the estimation of N(60). The median of the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios gives the completeness of death registration as .223. That is to say only 22.3 per cent of all deaths which occurred in 1979 were reported or registered in the same year. Table 3.2.2 shows the estimates of the completeness of death registration when e(60)= 15 years was used in the estimation of N(60). The value of e(60) = 15 years was obtained from the Coale- Demeny[8] (1966) life tables model North level 15. Model North level 15 was used to estimate e(60) since most often, the mortality level of Kenya has been said to be roughly aproximated by it. From table 3.2.2, the median of the ${}_{10}\hat{N}_{a-5}/$ ${}_{10}N_{a-5}$ ratios is given as .224. Thus if e(60) = 15 years is used as an input in the estimation of N(60), then only 22.4 per cent of all deaths which occurred in 1979 were registered in the same year. We have also used the value of e(60) = 13.9 years for males in the estimation of N(60). The value of e(60) = 13.9 years was obtained from the Coale- Demeny life tables model "West" level 15. Its results are shown in table 3.2.3. The median of the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios shows that only 22.1 per cent of all deaths were registered.

Now instead of using equation (3.2.3) which needs the value of e(60) in order to estimate N(60), we estimate N(60) by the alternative method which does not require e(60) as an input. That is, we approximate N(60) by the formula

$$N(60) = D(60+) \exp [r(60+)\ Z(60)].$$

Where Z(60) is approximated by equation (3.2.7) and the coefficients of Z(60) are obtained from table A.3 in the appendix. N(60) has been approximated as equal to 6420. Then following the procedures outlined above for estimating the completeness of death registration, table 3.2.4 shows that only 22.2 per cent of all deaths were recorded.

Table 3.2.5 is now a summary of the ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios for males in the estimation of the completeness of death registration in 1979 at truncation age 60 when the different values of e(60) are used in the estimation of N(60) and for the case in which N(60) is estimated independently of e(60). It is observed from this table, table 3.2.5, that the per cent difference among the ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios at each age group is less than .5 per cent and that the per cent difference of the medians of the ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios is less than .4 per cent. That is to say, the choice of e(60) or the treatment of the open interval (estimation of N(60)) does not seem to significantly affect the degree of the completeness of death registration among males.

In order to study the consistency of the basic male data used to estimate the completeness of death registration above, sets of completeness estimates have been calculated with different truncation ages (A = 60, 55, 50). For each truncation age, the different techniques of estimating N(A) are employed. In addition to table 3.2.1 in which e(60) = 14.6 years was used to estimate N(60) in the estimation of the completeness of death registration; tables 3.2.6 and 3.2.7 show the results obtained when e(55) = 18.0 years and e(50) = 21.7 years are used to estimate N(55) and N(50) respectively using equation (3.2.2). The values of e(55) = 18.0 years and e(50) = 21.7 years were obtained from the 1979 Kenya National Model life tables. Table 3.2.6 gives the median of the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios as .222 while table 3.2.7 gives the median of the ratios as .223. Thus if e(A) {A=60, 55, 50} is used in the estimation of N(A), the degrees of completeness of death registration are .223, .222 and .223 for truncation ages 60, 55 and 50 respectively.

If on the other hand N(A) (A = 60, 55, 50) is estimated independently of e(A), for truncation age 60, the completeness has been estimated as equal to .222 in table 3.2.4. For truncation ages 55 and 50, from tables 3.2.8 and 3.2.9 the completeness of death registration is estimated as equal to .222 and .225 respectively.

Table 3.2.10 is now a summary of the ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios for the different truncation ages (A=60,55, 50) and for the different treatments of the open interval. It is observed from table 3.2.10 that, if N(A), for all values of A, is approximated with e(A) as an input in its approximation, the difference in the medians of the ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios is less than .2 per cent. On the other hand table 3.2.10 shows that if N(A) (A = 60,55,50) is approximated independent of e(A) for all values of A, the per cent difference of the degrees of completeness is less than or equal to .3 per cent. Thus in both cases of the treatment of the open interval, the per cent difference of the degrees of completeness is less than .5 per cent. We can therefore say at this point that with the available information and with the truncation ages considered, the degree of completeness of death registration for males does not vary much with truncation age.

A study for the completeness of death registration for females in Kenya in 1979 has also been carried out. As was the case for males, we have started by taking different values of e(60) in the estimation of N(60). Values of e(60) used in the estimation N(60) are 15.4 years (obtained from the 1979 Kenya National life tables). Incidentally e(60)= 15.5 years for females by the Coale-Demeny life tables model "West" level 15. Therefore in this study, a table of the completeness of death registration estimates for e(60) = 15.5 years has not been given since its values are nearly the same as those given when e(60) = 15.4 years. The value of e(60) = 16 years was obtained from the Coale- Demeny life tables model "North" level 15. Estimates of the completeness of death registration when N(60) is estimated independently of e(60) have also been worked out.

For e(60) = 15.4 years, and e(60) = 16 years, the medians of the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios are .143 and .135 respectively from tables 3.2.11 and 3.2.12. Table 3.2.13 shows that if N(60) is estimated independently of e(60), the medians of the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios gives the completeness of death registration as equal to .135. Now table 3.2.14 is a summary of the ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ ratios in which the two e(60) values are used to estimate N(60) and when N(60) is estimated independently of e(60).

From table 3.2.14 it is observed that the per cent difference of the degrees of completeness as given by the medians of the $_{10}\hat{N}_{a-5}$ / $_{10}N_{a-5}$ ratics is less than or equal to .8. This per cent difference in the degrees of completeness with truncation age 60 is relatively higher than that for males (.2 per cent). Further it is observed that the per cent difference in the $_{10}\hat{N}_{a-5}$ / $_{10}N_{a-5}$ ratios at each age is higher among females relative to that for males. The maximum per cent difference is however less than 1 per cent. Since a per cent difference of 1 is small, we can conclude as was the case for males that at age 60, the degree of the completeness of death registration does vary much with the choice of e(60) or technique of estimating e(60).

Further as in the case for males, we study the consistency of the basic female data for the estimation of the completeness of death registration. For this, different truncation ages (A = 60, 55 and 50) have been considered as was the case for males, in estimating the completeness of death registration. Values of e(A) (A = 60, 55 and 50) used in the estimation of N(A) were obtained from the 1979 Kenya National life tables. Table 3.2.15 and 3.2.16 shows female deaths, population, the rates of growth by age and values of $\hat{N}(a)$, $_5\hat{N}_a$, and the $_{10}\hat{N}_{a-5}$ / $_{10}N_{a-5}$

ratios for Kenya 1979 when e(55) = 19.1 years and e(50) = 23.0 years are used as inputs in estimating N(55) and N(50) respectively. Table 3.2.15 gives the median of the ratios as equal to .129, while table 3.2.16 gives the median of the ratios as being equal to .131.

If N(A) (A = 55, 50) is estimated independently of e(A), table 3.2.17 estimates the completeness of death registration as equal to .130 for truncation age 55, and table 3.2.18 gives the completeness of death registration as equal to .127 if truncation age is 50 years.

Table 3.2.19 is a summary of the female ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios by age for Kenya in 1979 for different truncation ages (A = 60, 55, 50) and for the different treatments of the open interval. It is observed from table 3.2.19 that if e(A) (A = 60, 55 and 50) is used as input in the estimation of N(A), the per cent difference an the degrees of completeness is less than .6 and that the difference among the ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ ratios falls with age. For the case in which N(A) (A = 60, 55 and 50) is estimated independently of e(A), table 3.2.19 shows that the maximum per cent difference in the completeness of death registration is .8 per cent. It is also observed that the per cent difference in the degree of completeness of death registration at any age is less than or equal to .2 per cent.

Table 3.2.19 shows that if we consider a per cent difference greater than .6 as large enough, then we can say that for females unlike the case for males, the degree of completeness of death registration is affected by truncation age. This suggests the presence of age reporting errors. If we however consider any per cent difference in the degrees of completeness less than 1 per cent as negligible, then, we can conclude that for females as for males, truncation age does not significantly affect the degree of completeness of death registration and that the treatment of the open interval at a given truncation age does not significantly affect the degree of completeness.

From tables 3.2.10 and 3.2.19, we can then approximate the completeness of death registration in Kenya in 1979 as 22.2 per cent for males and 12.7 per cent for females respectively. Thus all deaths in 1979 have to be inflated by a factor $^1/.222 = 4.50$ for males and $^1/.127 = 7.87$ for females respectively. This has been done and is displayed in table 3.2.20 and 3.2.21 respectively. We also note from the findings that male deaths were registered relatively better than female deaths.

If we consider the $_{10}\hat{N}_{a-5}$ / $_{10}N_{a-5}$ ratios for truncation age 60 and when e(60) values are used as inputs in the estimation of N(60) for males and females as representative estimates of the completeness of death registration, then figure 3.2.1 and 3.2.2 show the variations of ${}_{10}\hat{N}_{a-5} / {}_{10}N_{a-5}$ with respect to age. The deviations of the ratios from a straight line indicate errors due to either to age misreporting or differential enumeration of the 1969 and 1979 censuses.

Degrees of completeness of death registration of 22.2 per cent for males and 12.7 per cent for females shows that the completeness of death registration is poor. Therefore unless death statistics in Kenya are corrected for underregistration, indirect methods of mortality estimations should be used when dealing with the death statistics.

Table 3.2.1: Male deaths, Population, and rates of growth by age and values of $\hat{N}(a)$, ${}_5\hat{N}_a$, and ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ for Kenya 1979 {e(60) = 14.6 years}.

Age	Age Specific Growth Rate ${}_5r_a$	Number of Deaths 1979 ${}_5D_a$	1979 Population ${}_5N_a$	$\hat{N}(a)$	Estimated 1979 Population ${}_5\hat{N}_a$	${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$
0	.02977	7739	1 424 954	74 610	329 293	---
5	.0310	803	1 249 662	57 107	263 178	.222
10	.03876	445	1 053 099	48 164	218 598	.209
15	.04239	427	855 884	39 275	176 663	.207
20	.04066	452	642 723	31 390	141 560	.212
25	.03884	566	515 512	25 234	113 750	.220
30	.03687	558	406 221	20 266	91 528	.223
35	.01428	578	290 825	16 345	77 515	.243
40	.03009	629	262 019	14 661	66 728	.261
45	.02403	638	219 365	12 030	55 243	.253
50	.03247	763	183 285	10 067	44 805	.248
55	.02072	675	141 067	78 55	35 740	.248
60	.01611	5128	362 497	64 41	---	---
						Median =.223

e(60) = 14.6 years {Kenya National Model life tables 1979}.

Table 3.2.2 Male deaths, Population, and rates of growth by age and Values of $\hat{N}(a)$, ${}_5\hat{N}_a$: and ${}_{10}\hat{N}_{a-5}$ / ${}_{10}N_{a-5}$ for Kenya 1979 {e(60) = 15 years}.

Age	${}_5r_a$	${}_5D_a$	1979 Population ${}_5N_a$	$\hat{N}(a)$	${}_5\hat{N}_a$	${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$
0	.02977	7739	1 424 954	74 871	330 508	---
5	.0310	803	1 249 662	57 332	264 223	.222
10	.03876	445	1 053 099	48 357	219 478	.210
15	.04239	427	855 884	39 434	177 380	.208
20	.04066	452	642 723	31 518	142 140	.213
25	.03804	508	515 512	25 388	114 225	.221
30	.03687	558	406 221	20 352	91 923	.224
35	.01428	578	290 825	16 417	77 863	.244
40	.03009	629	262 019	14 728	67 038	.262
45	.02403	638	219 365	12 087	55 513	.255
50	.03247	763	183 285	10 118	45 040	.250
55	.02072	675	141 067	78 98	35 945	.250
60	.01611	5128	362 497	64 80	---	---
						Median = .224

e(60) = 15 years {Coale - Demeny (1966) Life tables Model North level 15}.

Table 3.2.3 Male deaths, Population, and Annual Rates of Growth by Age and Values of $\hat{N}(a)$; ${}_5\hat{N}_a$; and ${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$ for Kenya 1979 {e(60) = 13.9 years}.

Age	${}_5r_a$	${}_5D_a$	1979 Population ${}_5N_a$	$\hat{N}(a)$	${}_5\hat{N}_a$	${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$
0	.02977	7739	1 424 954	74 149	327 148	---
5	.0310	803	1 249 662	56 710	261 335	.220
10	.03876	445	1 053 099	47 824	217 048	.208
15	.04239	427	855 884	38 995	175 395	.206
20	.04066	452	642 723	31 163	140 528	.211
25	.03884	566	515 512	25 048	112 903	.219
30	.03687	558	406 221	20 113	90 828	.221
35	.01428	578	290 825	16 218	76 903	.241
40	.03009	629	262 019	14 543	66 178	.259
45	.02403	638	219 365	11 928	54 763	.251
50	.03247	763	183 285	99 77	44 388	.246
55	.02072	675	141 067	77 78	35 375	.246
60	.01611	5128	362 497			
						Median=.221

e(60) = 13.9 years {Coale - Demeny (1966) Life tables Model West level 15}.

Table 3.2.4 Male deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$ and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 {TRUNCATION AGE = 60}.

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.02977	7739	1 424 954	74 533	328 935	---
5	.031	803	1 249 662	57 041	262 873	.221
10	.03876	445	1 053 099	48 108	218 343	.209
15	.04239	427	855 884	39 229	176 453	.207
20	.04066	452	642 723	31 352	141 320	.212
25	.03884	566	515 512	25 176	113 488	.220
30	.03687	558	406 221	20 219	91 313	.222
35	.01428	578	290 825	16 306	77 328	.242
40	.03009	629	262 019	14 625	66 560	.260
45	.02403	638	219 365	11 999	55 098	.253
50	.03247	763	183 285	10 040	44 680	.248
55	.02072	675	141 067	7 832	35 630	.248
60	.01611	5128	362 497	6 420	---	
						Median=.222

N(60) Approximated using the equation N(60) = D(60+) {exp[r(60+) Z(60)] } Where Z(60)= a(60)+b(60) r(60)+C(60) exp {D(45+)/D(10+)} and the coefficients are obtained from West Mortality Model.

Table 3.2.5 $_{10}\hat{N}_{a-5}$ / $_{10}N_{a-5}$ Ratios for Males in the Estimation of the Completeness of Death Registration 1979.

Age	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ Using $e(60)=14.6^{(1)}$ years	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ Using $e(60)=15^{(2)}$ years	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ Using $e(60)=13.9^{(3)}$ years	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$*
0-4				
5-9	.222	.222	.220	.221
10-14	.209	.210	.208	.209
15-19	.207	.208	.206	.207
20-24	.212	.213	.211	.212
25-29	.220	.221	.219	.220
30-34	.223	.224	.221	.222
35-39	.243	.244	.241	.242
40-44	.261	.262	.259	.260
45-49	.253	.255	.251	.253
50-54	.248	.250	.246	.248
55-59	.248	.250	.246	.248
60 +				
	Median = .223	Median = .224	Median = .221	Median= .222

1. e(60) = 14.6 obtained from the Kenya Model Life tables (1979).
2. e(60) = 15 years obtained from using Coale and Demeny (1966) life tables Model North level 15.
3. e(60) = 13.9 years obtained using Model West level 15.

* No value of e(60) is needed in the estimation of N(60) $\hat{N}(60) = D(60+)\{\exp[r(60+)\ Z(60)]\}$.

Table 3.2.6 Male deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, ${}_5\hat{N}_a$, and ${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$ for Kenya 1979.

{TRUNCATION AGE = 55 YEARS}

Age	Age Specific Growth Rate ${}_5r_a$	No. of Death 1979 ${}_5D_a$	1979 Population ${}_5N_a$	$\hat{N}(a)$	Estimated 1979 Population ${}_5\hat{N}_a$	${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$
0	.02977	7739	1 424 954	74 581	329 158	—
5	.031	803	1 249 662	57 082	263 063	.221
10	.03876	445	1 053 099	48 143	218 500	.209
15	.04239	427	855 884	39 257	176 580	.207
20	.04066	452	642 723	31 375	141 425	.212
25	.03884	566	515 512	25 195	113 573	.220
30	.03687	558	406 221	20 234	91 383	.222
35	.01428	578	290 825	16 319	77 390	.242
40	.03009	629	262 019	14 637	66 615	.260
45	.02403	638	219 365	12 009	55 145	.253
50	.03247	763	183 285	10 049	44 723	.248
55+	.01738	5803	503 564	78 40	---	
						Median=.222

e(55) = 18.0 years {Kenya Model Life tables 1979}.

Table 3.2.7 Male deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979.

{TRUNCATION AGE = 50 YEARS}

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.02977	7739	1 424 954	75 196	332 020	---
5	.031	803	1 249 662	57 612	265 523	.223
10	.03876	445	1 053 099	48 597	220 570	.211
15	.04239	427	855 884	39 631	178 273	.209
20	.04066	452	642 723	31 678	142 800	.214
25	.03884	566	515 512	25 442	114 700	.222
30	.03687	558	406 221	20 438	92 315	.225
35	.01428	578	290 825	16 488	78 205	.245
40	.03009	629	262 019	14 794	67 345	.263
45	.02403	638	219 365	12 144	55 780	.256
50+	.02119	6566	686 849	10 168	---	
						Median=.223

$e(50) = 21.7$ years {Kenya Model Life Tables 1979}.

Table 3.2.8 Male deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$ and $_5\hat{N}_a$ and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 {TRUNCATION AGE 55}

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.02977	7739	1 424 954	74 462	328 605	---
5	.031	803	1 249 662	56 980	262 588	.221
10	.03876	445	1 053 099	48 055	218 100	.209
15	.04239	427	855 884	39 185	176 255	.207
20	.04066	452	642 723	31 317	141 160	.212
25	.03884	566	515 512	25 147	113 355	.220
30	.03687	558	406 221	20 195	91 203	.222
35	.01428	578	290 825	16 286	77 230	.242
40	.03009	629	262 019	14 606	66 470	.260
45	.02403	638	219 365	11 982	55 018	.252
50	.03247	763	183 285	10 025	44 610	.247
55	.01738	5803	503 564	78 19	- - -	
						Median=.222

N(55) Approximated using the equation $N(55) = D(55+)\{\exp[r(55+)\, Z(55)]\}$

Where $Z(55) = a(55) + b(55)\, r(55+) + C(55) \exp\{D(45+)/D(10+)\}$ and the coefficients are obtained from West Mortality Model.

Table 3.2.9 Male deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, ${}_5\hat{N}_a$ and ${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$ for Kenya 1979

{TRUNCATION AGE = 50 }

Age	Age Specific Growth Rate ${}_5r_a$	No. of Deaths 1979 ${}_5D_a$	1979 Population ${}_5N_a$	$\hat{N}(a)$	Estimated 1979 Population ${}_5\hat{N}_a$	${}_{10}\hat{N}_{a-5}/{}_{10}N_{a-5}$
0	.02977	7739	1 424 954	75 652	334 143	- - -
5	.031	803	1 249 662	58 005	267 345	.225
10	.03876	445	1 053 099	48 933	222 103	.213
15	.04239	427	855 884	39 908	179 525	.210
20	.04066	452	642 723	31 902	143 818	.216
25	.03884	566	515 512	25 625	115 533	.224
30	.03687	558	406 221	20 588	93 003	.226
35	.01428	578	290 825	16 613	78 808	.246
40	.03009	629	262 019	14 910	67 885	.265
45	.02403	638	219 365	12 244	56 253	.258
50	.02119	6566	686 849	10 257	- - -	
						Median = .225

N(50) approximated using the equation $N(50) = D(50+)\{\exp[r(50+)Z(50)]\}$

Where $Z(50) = a(50) + b(50)\,r(50+) + C(50)\exp\{D(45+)/D(10+)\}$ and coefficients are obtained from West Mortality Model.

Table 3.2.10 Male $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 for Different Truncation Ages and Different Treatment of the Open Interval

	$N(A)= D(A+)\{\exp[r(A+)e(A)] -([r(A+)e(A)]^2/6)\}$			$N(A)=D(A+)\{\exp[r(A+)Z(A)]\}$		
Age	TRUNCATION AGE (A)			TRUNCATION AGE (A)		
X	60	55	50	60	55	50
0						
5	.222	.221	.223	.221	.221	.225
10	.209	.209	.211	.209	.209	.213
15	.207	.207	.209	.207	.207	.210
20	.212	.212	.214	.212	.212	.216
25	.220	.220	.222	.220	.220	.224
30	.223	.222	.225	.222	.222	.226
35	.243	.242	.245	.242	.242	.246
40	.261	.260	.263	.260	.260	.265
45	.253	.253	.256	.253	.252	.258
50	.248	.248		.248	.247	
55	.248			.248		
60						
Median	.223	.222	.223	.222	.222	.225

1) For the estimation of N(A), using the equation $N(A)= D(A+)\{\exp[r(A+)e(A)]- ([r(A+)e(A)]^2/6)\}$, the e(A), (A=50, 55, 60) are obtained from the Kenya 1979 Model Life Tables.

2) For the estimation of $N(A)= D(A+)\{\exp[r(A+) Z(A)]\}$, where $Z(A)= a(A)+b(A\ r(A+)+C(A)\exp\{D(45+)/D(10+)\}$ the coefficients are obtained from West Mortality Model.

Table 3.2.11 Female deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(A)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 (Estimation of the Completeness of Death Registration.

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated Population 1979 $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.03081	6939	1 423 936	50 366	217 793	- - -
5	.03335	702	1 246 983	36 751	168 030	.144
10	.04351	357	1 025 677	30 461	136 615	.134
15	.04899	340	889 316	24 185	107 038	.127
20	.04232	341	687 234	18 630	83 500	.121
25	.02765	352	542 233	14 770	68 260	.123
30	.03232	316	413 432	12 534	57 265	.131
35	.02077	338	325 951	10 372	48 500	.143
40	.03059	269	274 193	9 028	41 315	.150
45	.03053	304	222 363	7 498	34 133	.152
50	.03192	350	191 365	6 155	27 698	.149
55	.02763	277	134 776	4 924	22 385	.154
60	.02035	2839	342 488	4 030	---	---
						Median= .143

e(60) = 15.4 years (Model West Level 15).

Table 3.2.12 Estimation of the Completeness of Death Registration for the Total Female Population Using the Neil G. Bennett and Shiro Horiuchi Method.

Age Group	1969 Population	1979 Population	Age Specific Growth Rate $_5r_a$	$_5D_a$	$_5N_a$	$\hat{N}(a)$	$_5\hat{N}_a$	$_{10}\hat{N}_{a-5}$	$_{10}N_{a-5}$	$\frac{_{10}\hat{N}_{a-5}}{_{10}N_{a-5}}$
0-4	1 046 380	1 423 936	.03081	693[illegible]	1 423 936	49 263	212 670			
5-9	893 359	1 246 983	.03335	702	1 246 983	35 805	163 663	376 333	2 670 919	.141
10-14	663 808	1 025 677	.04351	357	1 025 677	29 660	133 003	296 666	2 272 660	.131
15-19	544 847	889 316	.04899	340	889 316	23 541	104 168	237 171	1 914 993	.124
20-24	450 096	687 234	.04232	34[illegible]	687 234	18 126	81 220	185 388	1 576 550	.118
25-29	411 245	542 233	.02765	352	542 233	14 362	66 353	147 573	1 229 467	.120
30-34	299 241	413 432	.03232	316	413 432	12 179	55 623	121 976	955 665	.128
35-39	264 819	325 951	.02077	338	325 951	10 070	47 065	102 688	739 383	.139
40-44	201 936	274 193	.03059	269	274 193	8 756	40 053	87 118	600 144	.145
45-49	163 852	222 363	.03053	301	222 363	7 265	33 050	73 103	496 556	.147
50-54	139 072	191 365	.03192	350	191 365	5 955	26 770	59 820	413 728	.145
55-59	102 235	134 776	.02763	277	134 776	4 753	21 585	48 355	326 141	.148
60+	279 434	342 488	.02035	2839	342 488	3 881	- - -			
										Median = .135

e(60) = 16 years (Coale-Demeny 1966 Life table Model North level 15).

Table 3.2.13 Female deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 (TRUNCATION AGE = 60 YEARS).

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.03081	6939	1 423 936	48 221	207 833	---
5	.03335	702	1 246 983	34 912	159 540	.138
10	.04351	357	1 025 677	28 904	129 593	.127
15	.04899	340	889 316	22 933	101 458	.121
20	.04232	341	687 234	17 650	79 068	.115
25	.02765	352	542 233	13 977	64 553	.117
30	.03232	316	413 432	11 844	54 073	.124
35	.02077	338	325 951	9 785	45 710	.135
40	.03059	269	274 193	8 499	38 858	.141
45	.03053	304	222 363	7 044	32 023	.142
50	.03192	350	191 365	5 765	25 890	.140
55	.02763	277	134 776	4 591	20 828	.143
60	.02035	2839	342 488	3 740	- - -	
						Median=.135

$\hat{N}(60)$ Approximated using the equation $N(60) = D(65+)\{\exp[r(60).\ Z(60)]\}$ Where $Z(60) = a(60)+b(60)\ r(60+) + C(60)\exp\ \{D(45+)/D(10+)\}$ and the coefficients are obtained from West Mortality Model.

Table 3.2.14 $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ Ratios for Females in the Estimation of The Completeness of Death Registration 1979.

Age	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ Using e(60) = 15.4 Years	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ Using e(60) = 16 Years	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0-4			
5-9	.144	.141	.138
10-14	.134	.131	.127
15-19	.127	.124	.121
20-24	.121	.118	.115
25-29	.123	.120	.117
30-34	.131	.128	.124
35-39	.143	.139	.135
40-44	.150	.145	.141
45-49	.152	.147	.142
50-54	.149	.145	.140
55-59	.154	.148	.145
60 +			

Median = .143 Median = .135 Median = .135

Table 3.2.15 Female deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 (TRUNCATION AGE = 55 YEARS).

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$\frac{_{10}\hat{N}_{a-5}}{_{10}N_{a-5}}$
0	.03081	6939	1 423 936	48 797	210 508	– – –
5	.03335	702	1 246 983	35 406	161 820	.139
10	.04351	357	1 025 677	29 322	131 478	.129
15	.04899	340	889 316	23 269	102 955	.122
20	.04232	341	687 234	17 913	80 258	.116
25	.02765	352	542 203	14 190	65 546	.119
30	.03232	316	413 432	12 029	54 930	.126
35	.02077	338	325 951	9 943	46 460	.137
40	.03059	269	274 193	8 641	39 518	.143
45	.03053	304	222 363	7 166	32 590	.145
50	.03192	350	191 365	5 870	26 378	.143
55	.02235	3116	477 264	4 681	– – –	
						Median=.129

e(55) = 19.1 /Kenya Model Life Tables 1979/.

Table 3.2.16 Female deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 (TRUNCATION AGE = 50 YEARS).

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.03081	6939	1 423 936	49 346	213 055	---
5	.03335	702	1 246 983	35 876	163 990	.141
10	.04351	357	1 025 677	29 720	133 273	.131
15	.04899	340	889 316	23 589	104 380	.124
20	.04232	341	687 234	18 163	81 388	.118
25	.02765	352	542 233	14 392	66 493	.120
30	.03232	316	415 432	12 205	55 743	.128
35	.02077	338	325 951	10 092	47 170	.139
40	.03059	269	274 193	8 776	40 145	.145
45	.03053	304	222 363	7 282	33 128	.148
50	.0250	3466	668 629	5 969	---	
						Median= .131

e(50) = 23 Years (Kenya Model Life tables 1979).

Table 3.2.17 Female deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 (TRUNCATION AGE 55)

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.03081	6939	1 423 936	47 834	206 035	- - -
5	.03335	702	1 246 983	34 580	158 008	.136
10	.04351	357	1 025 677	28 623	128 325	.126
15	.04899	340	889 316	22 707	100 450	.119
20	.04232	341	687 234	17 473	78 268	.113
25	.02765	352	542 233	13 834	63 883	.116
30	.03232	316	413 432	11 719	53 495	.123
35	.02077	338	325 951	9 679	45 205	.134
40	.03059	269	274 193	8 403	38 413	.139
45	.03053	304	222 363	6 962	31 643	.141
50	.03192	350	191 365	5 695	25 568	.138
55	.02235	3116	477 264	4 532	- - -	

Median = .13

N(55) approximated using the equation N(A) = D(A+) exp (r(A).Z(A)).

Where Z(A)= a(A) + b(A) r(A) exp {D(45+)/D(10+)}

Coefficients of Z(A) obtained from the West Mortality Model.

Table 3.2.18 Female deaths, Population, and Rates of Growth by Age and Values of $\hat{N}(a)$, $_5\hat{N}_a$, and $_{10}\hat{N}_{a-5}/_{10}N_{a-5}$ for Kenya 1979 (TRUNCATION AGE 50)

Age	Age Specific Growth Rate $_5r_a$	No. of Deaths 1979 $_5D_a$	1979 Population $_5N_a$	$\hat{N}(a)$	Estimated 1979 Population $_5\hat{N}_a$	$_{10}\hat{N}_{a-5}/_{10}N_{a-5}$
0	.03081	6939	1 423 936	48 251	207 973	---
5	.03335	702	1 246 983	34 938	159 660	.138
10	.04351	357	1 025 677	28 926	129 690	.127
15	.04899	340	889 316	22 950	101 533	.121
20	.04232	341	687 234	17 663	79 128	.115
25	.02765	352	542 233	13 988	64 603	.117
30	.03232	316	413 432	11 853	54 115	.124
35	.02077	338	325 951	9 793	45 748	.135
40	.03059	269	274 193	8 506	38 890	.141
45	.03053	304	222 363	7 050	32 050	.143
50	.0250	3466	668 629	5 770	- - -	

Median = .127

$\hat{N}(50)$ approximated using the equation $N(A) = D(A+) \exp\{r(A)\, Z(A)\}$ Where $Z(A) = a(A) + b(A)\, r(A) + C(A) \exp\{D(45+)/D(10+)\}$ and the coefficients are obtained from the West Mortality Model.

Table 3.2.19 Female $10^{N}a-5/10^{N}a-5$ for Kenya 1979 for Different Truncation Ages and Different Treatment of the Open Interval.

	$N(A)=D(A+)\{\exp[r(A+)e(A)]-([r(A+)e(A)]^{2}/6)\}$			$N(A)=D(A+)\{\exp[r(A+)Z(A)]\}$		
Age	TRUNCATION AGE (A).			TRUNCATION AGE (A)		
X	60	55	50	60	55	50
0						
5	.144	.139	.141	.138	.136	.138
10	.134	.129	.131	.127	.126	.127
15	.127	.122	.124	.121	.119	.121
20	.121	.116	.118	.115	.113	.115
25	.123	.119	.120	.117	.116	.117
30	.131	.126	.128	.124	.123	.124
35	.143	.137	.139	.135	.134	.135
40	.150	.143	.145	.141	.139	.141
45	.152	.145	.148	.142	.141	.143
50	.149	.143		.140	.138	
55	.154			.143		
60						
Median	.135	.129	.131	.135	.130	.127

1) For the estimation of N(A) using the equation $N(A)=D(A+)\{\exp[r(A+)e(A)]-([r(A+)e(A)]^{2}/6)\}$, the e(A), A=50, 55, 60, are obtained from the Kenya 1979 Model Life Tables.

2) For the estimation of $N(A)= D(A+)\{\exp[r(A+)\ Z(A)]\}$, Where $Z(A)= a(A)+b(A)\ r(A+) + C(A)\exp\{D(45+)/D(10+)\}$, the coefficients are obtained from West Mortality Model.

Table 3.2.20 Male deaths and Age Specific Death Rates by Age

Age	$(_5N_a)$ 1979 Population Adjusted	Observed		Adjusted	
		Number of Deaths $_5D_a$	Age Specific Mortality Rate $_5M_a$	Number of Deaths $_5D^*_a$	Age Specific Mortality Rate $_5M^*_a$
0	1 424 954	77 39	.00543	34 826	.02444
5	1 249 662	803	.00064	3 614	.00289
10	1 053 099	445	.00042	2 003	.00190
15	855 834	427	.00050	1 922	.00225
20	642 723	452	.00070	2 034	.00316
25	515 512	566	.00110	2 547	.00494
30	405 221	558	.00137	2 511	.00618
35	290 825	578	.00199	2 601	.00894
40	262 019	629	.0024	2 831	.0108
45	219 335	638	.00291	2 871	.01309
50	183 285	763	.00416	3 434	.01873
55	141 067	675	.00478	3 038	.02153
60	107 932	902	.00836	4 059	.03761
65	100 112	781	.00780	3 515	.03511
70	66 506	869	.01307	3 911	.05880
75+	87 947	2576	.02929	11 592	.13181

$_5M_a = \frac{_5D_a}{_5N_a}$ Take degree of completeness = .222

$\therefore$ Adjusting factor = $\frac{1}{.222}$ = 4.50 $\therefore$ $_5D^*_a = 4.5 \times {_5D_a}$

Table 3.2.21 Female Deaths and Age Specific Death Rates by Age

Age	1979 Population Adjusted $_5N_a$	Observed		Adjusted	
		Number of deaths 1979 $_5D_a$	Age Specific Death Rate $_5M_a$	Number of Deaths $_5D^*_a$	Age Specific Death Rate $_5M^*_a$
0	1 423 936	6939	.00487	54 610	.03835
5	1 246 983	702	.00056	5 525	.00443
10	1 025 677	357	.00035	2 810	.00274
15	889 316	340	.00038	2 676	.00301
20	687 234	341	.00050	2 684	.00391
25	542 233	352	.00065	2 770	.00511
30	413 432	316	.00076	2 487	.00612
35	352 951	338	.00096	2 660	.00754
40	274 193	269	.00098	2 117	.00772
45	222 363	304	.00137	2 392	.01076
50	191 365	350	.00183	2 755	.01439
55	134 776	277	.00206	2 180	.01617
60	109 715	482	.00439	3 793	.03457
65	83 370	368	.00441	2 896	.03474
70	62 651	413	.00659	3 250	.05188
75+	86 752	1576	.01817	12 403	.14297

$$_5M_a = \frac{_5M_a}{_5N_a}$$

Take degree of completeness for Females 1979 be .127. Therefore correction factor = 1/.127=7.87

$\therefore \; _5D^*_a = {_5D_a} \times 7.87$

Fig.3.2.1 A GRAPH OF $10^{\hat{N}}{}_{a-5}/10^{N}{}_{a-5}$ AGAINST AGE FOR MALES : 1979

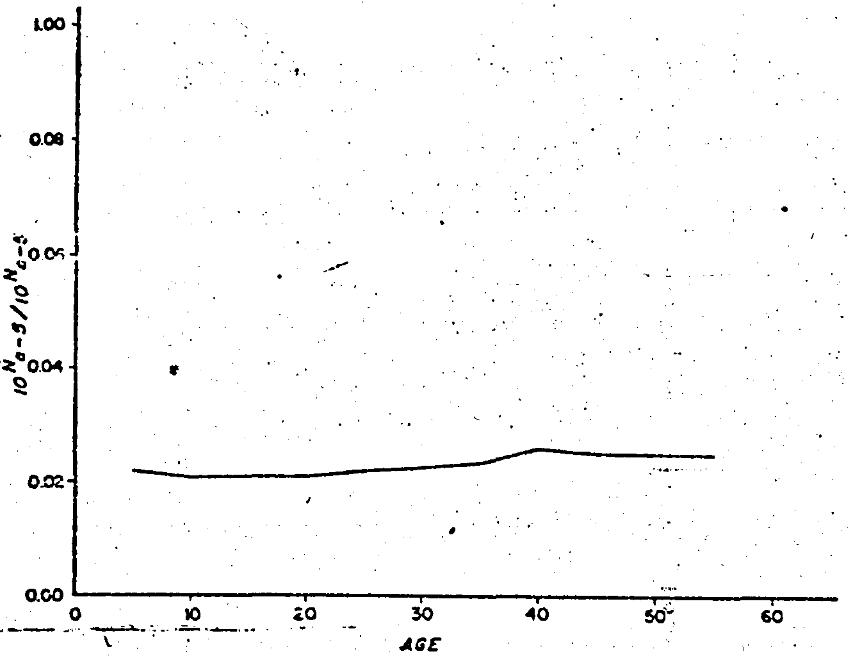
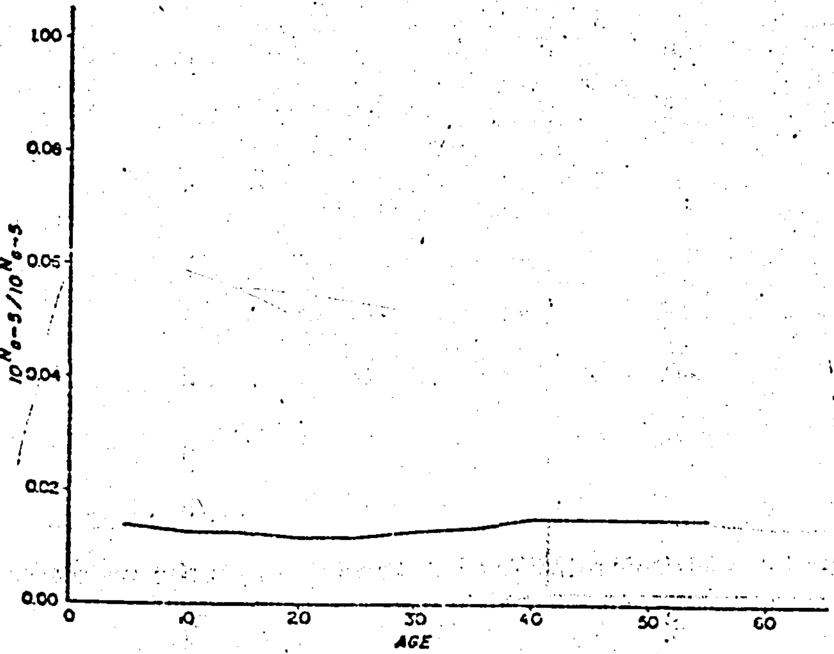


Fig.3.2.2 A GRAPH OF $10^{\hat{N}}{}_{a-5}/10^{N}{}_{a-5}$ AGAINST AGE FOR FEMALES : 1979



3.3 APPLICATION OF METHOD II: LIFE TABLE CONSTRUCTION FROM INCOMPLETE DEATH REGISTRATION DATA:

A study of the completeness of death registration in Kenya in 1979 relative to the 1979 population as enumerated by age and sex in Section 3.2 above indicated that only 22.2 per cent of all male deaths were registered and that only 12.7 per cent of all female deaths were registered. Direct use of the death statistics in Kenya without adjustment (for underregistration) will therefore lead to biased estimates of the levels of mortality.

For this matter, an indirect method of life table construction from incomplete death registration data is used in the construction of life tables for Kenya using the 1979 number of registered deaths by age and sex. The method uses age specific growth rates, and since one of the major approaches to mortality estimation using age specific growth rates is the conversion of the age distribution of deaths occurring in the observed population into the distribution of deaths in the life table, using the method, one can construct life tables which are corrected for any under-enumeration of the population or under-registration of deaths. Prior knowledge of the level of completeness of recording of deaths and population is not necessary - the completeness should however not vary with age. The method is applicable to any closed population and essentially derives from extensions to stable population theory.

In the construction of life tables and with the usual notations, we start with the formula,

$$ {}_5\bar{r}_a = \frac{\hat{N}(a+5)}{\hat{N}(a)} \exp\left(5.\ {}_5r_a\right) \quad \ldots\ldots \quad (3.3.1) $$

which is the probability of survival from age 'a' to 'a+5'. ${}_5r_a$ is the annual age specific growth rate, $\hat{N}(a)$ and $\hat{N}(a+5)$ are numbers of persons aged 'a' and 'a+5' respectively and are estimated iteratively by equations (3.2.2) and (3.2.3) i.e.

$$ \hat{N}(a) = \hat{N}(a+5)\exp\{5.{}_5r_a\} + {}_5D_a \exp\{2.5\ {}_5r_a\} $$

$$ \text{for } a=0,5,10,\ldots\ldots A-5 $$

and

$$ \hat{N}(A) = D(A+)\{\exp[r(A+)e(A)] - ([r(A+)e(A)]^2/6)\} $$

Where A is the lower bound of the open interval, ${}_5D_a$ as defined above is the number of deaths occurring within the age group a to a+5, and D(A+) is number of deaths occurring at age A and above. Once ${}_5P_a$'s values have been computed, all other life table functions are computed.

We however note that in the estimation of $\hat{N}(A)$, the value of e(A) is needed as an input. For this matter, the following procedure which takes advantage of the relationship observed in the Coale-Demeny model life tables between the age distribution of deaths and the expectation of life in a given age is used.

Within each family (West, North, East or South) of the model life table system, there exist a one-to-one relationship between the ratio of adolescent and younger adult deaths (ages 10 to 40) to older adult deaths (ages 40 to 60), and the life expectancy at age x; for x = 60,... 95 (Coale-Demeny, 1981). Because of this correspondence, we can convert the age distribution of registered deaths into the life table death distribution, ${}_5d_a$.

This method can thus be summarised as follows:

Step-One

Compute ${}_5d_a$;

$${}_5d_a = \frac{1}{k.B}\,{}_5D_a \exp\{\sum_{x=0}^{a-5} {}_5r_x + 2.5\,{}_5r_a\} \qquad \text{... (3.3.2)}$$

Where ${}_5d_a$ is the life table deaths between ages 'a' and 'a+5', k is the completeness of death registration, B is the annual number of births in the population, ${}_5D_a$ and ${}_5r_a$ are as defined above.

Step-Two

By summing ${}_5d_a$ values, compute

$$30^{d}10 \; / \; 20^{d}40$$

which is the ratio of adolescent and younger adult deaths, $30^{d}10$, to older adult deaths, $20^{d}40$. Note that it is not necessary to know k and B since they appear in both the numerator and denominator of the ratio $30^{d}10/20^{d}40$ and hence cancel each other out.

Step-Three

Using the $30^{d}10/20^{d}40$ ratio, determine e(A) from table A.1 in the appendix in which ratios of $30^{d}10/20^{d}40$ and the corresponding values of e(75) through e(90) for males and females at many different levels of mortality are displayed.

Step-Four

Compute

$$\hat{N}(A) = D(A+)\{\exp[r(A+)e(A)] - ([r(A+)e(A)]^{2}/6)\}$$

Step-Five

Compute

$$\hat{N}(a) = \hat{N}(a+5)\exp\{5 \cdot {}_{5}r_{a}\} + {}_{5}D_{a}\exp\{2.5 \; {}_{5}r_{a}\}$$

for $a = 0, 5, \ldots, A-5$

Step-Six

Then compute

$$ {}_5P_a = \frac{\hat{N}(a+5)}{\hat{N}(a)} \exp\{5 \cdot {}_5r_a\} $$

for a = 0,5,10,...A-5

The other life table functions are then derived from the sequence of $5^{P}a$'s by the following formulae;

$$ {}_5Q_a = 1 - {}_5P_a \quad \ldots\ldots \quad (3.3.3) $$

Where $5^{Q}a$ is the probability of dying in the interval 'a' to 'a+5' after survival upto exact age 'a'.

$$ {}_5d_a = \ell_a \times {}_5Q_a \quad \ldots\ldots \quad (3.3.4) $$

Where ℓ_a is number of survivors upto age 'a', and ℓ_0 = 100,000 and $5^{d}a$ is as defined above.

$$ \ell_{a+5} = \ell_a - {}_5d_a \quad \ldots\ldots \quad (3.3.5) $$

$$ {}_5L_a = \frac{5}{2}(\ell_a + \ell_{a+5}) \ldots\ldots \quad (3.3.6A) $$

for a=0,5,..., A-5

$$ {}_\infty L_A = \ell_A \times e(A) \quad \ldots\ldots \quad (3.3.6B) $$

$5^{L}a$ = Number of person years between exact ages 'a' and 'a+5'

$$ T_a = \sum_{a=0}^{A-5} {}_5L_a + {}_\infty L_A \quad \ldots\ldots \quad (3.3.7) $$

T_a = Number of person years lived after age 'a'.

and

$$ e(a) = \frac{T_a}{\ell_a} \quad \ldots\ldots \quad (3.3.8) $$

Where e(a) is expectation of life at age a for all values of a.

In Step-Five; for $a \geq 60$, N(a) is approximated by the formula;

$$N(a) = N(a+5)\exp\{5.{}_5r_a\} + {}_5\gamma_a\ {}_5D_a \exp\{2.5\ {}_5r_a\}.$$

Where the correction factor $5^{\gamma}a$ is given by

$$5^{\gamma}a = 1.00-2.26\ 5^{r}a\ 5^{M}a + .218\ 5^{r}a - .826\ 5^{r}a^{2}.$$

Table 3.3.1 and 3.3.3 show the procedures of estimating life expectancy at age A(where A = 75 is the ~~lower bound~~ of the open interval) and the estimation of the N(a)'s (a = 0,5,.....75) for males and females respectively. Table 3.3.2(A) and 3.3.4(A) are displays of the life table functions derived using the results obtained in table 3.3.1 and 3.3.3 for males and females respectively. Life expectancy at age 75 was estimated as equal to 6.80 years for males and 6.15 years for females using the procedures described above.

In order to study the validity of the e(75) values obtained above, we need to compare them with the e(75) values obtained by a different method. For this purpose, we use the formula suggested by Coale and Horiuchi[9] (1982) for estimating e(A), where A is the lower bound of the open interval when the completeness of death registration is known. The formula is

$$e(A) = M(A)^{-1} \exp\{-.0951\ M(A)^{-1.4}\ r(A)\} \ldots 3.3.9)$$

which in our case gives

$$e(75) = M(75)^{-1} \exp\{-.0951\ M(75)^{-1.4}\ r(75)\}$$

Where M(75) is the death rate at age 75 and over, adjusted for underregistration of deaths, and r(75) is the annual age specific growth rate at age 75 and over.

Using the completeness of death registration equal to 22.2 per cent for males and 12.7 per cent for females as determined in Section 3.2, e(75) is estimated as equal to 7.52 years for males and 6.86 years for females. In the application of equation 3.3.9, the reciprocals of the degrees of completeness are used to inflate the M(75) values for males and females. The inflation factor for males is 4.50 while it is 7.75 for females.

Comparing the two sets of the e(75) values, we note that for males the values differ by .72 years while for females the values differ by .6 years. The life expectancy estimates obtained when e(75) = 7.75 years for males and e(75) = 6.86 years for females are used as inputs in the estimation of N(75) are relatively higher than those obtained when the e(75) = 6.80 years for males and e(75) = 6.15 years for females (except at birth for females). The mean of the differences between the sets of the life expectancy estimates is .37 years for males and .40 years for females. Unlike the case for males where the sequence of the differences shows no particular trend, the differences in the life expectacy estimates for females increases monotonically with age. That is as one moves downward in the age distribution, the difference declines.

Since for both males and females, the difference in the life expectancy estimates obtained when different values of e(75) are used as inputs in the estimation of N(75) is less than .4 years for males except at age 75, and less than .6 years for females, we may then say that the effect of an error in the estimation of e(A), where A is the lower bound of the open interval, on the other life expectancy estimates is small and the error is mitigated as one moves downward in the age distribution. Hence we can with some degree of certainity use the e(75) values obtained by the Bennett and Horiuchi[10] (1982) method.

Now, the life expectancy estimates displayed in tables 3.3.2(A) and 3.4.4(A) appear acceptable (they decline steadily as age increases except at age '0'). However, their validity cannot be judged directly from their values. That is because, though the method employed in the construction of the life tables is said to be corrected for any underenumeration of the population or underregistration of deaths, the method makes no correction for age misreporting.

For this reason, an idea about the internal consistency of the life expectancy estimates can be obtained by comparing them with the life expectancy values in a set of model life tables. A simple way of carrying out this comparison is by calculating ratios of the estimated set of life expectancies by age to the set pertaining to one of the families of model life tables. In this study, Model "West" level 15 has been selected. Since the Bennett and Horiuchi method of life table construction is said to take care of underregistration of deaths or underenumeration of the population, we would expect the age sequence of the ratios to be nearly level. Any deviations of the ratios from being level will be resulting largely from age misreporting errors.

Table 3.3.5 and 3.3.6 show the life expectancy estimates, corresponding life expectancy values in Model "West" level 15 and the ratios obtained from the two sets of life expectancies for males and females respectively. Characteristics of the ratios are grasped easily by referring to figure 3.3.1 and 3.3.2 where they have been displayed graphically. For both males and females, the ratios are not near level. For both males and females the ratio is maximum at age 65 and starts to decline afterwards. If we restrict ourselves to the ratios between age 5 and 60, we observe that the range of the ratios is small in females relative to that for male ratios. The range is .057 for females and .121 for males. Within the 5 to 60 years age range, it is further observed that except at age 60, the ratio increases monotonically with increase in age for females. For males, the ratio also increases monotonically with increase in age except at age 25.

Patterns of the ratios as displayed in figure 3.3.1 and 3.3.2 suggest that other than the life expectancy estimates obtained by this method, Method II, being relatively higher than the corresponding e_x values in the Model "West" level 15, the estimates are sensitive or affected by errors in age reporting. Thus, though the method takes care of underregistration of deaths or underenumeration of the population, and needs no prior knowledge of the degree of completeness of death registration, its life expectancy estimates are affected by errors in age reporting. The errors have been shown to be more prevalent among males than females.

Table 3.3.1 Estimation of e(75) for the Total Male Population in Kenya (1979) and the N(x) /‾x = 0,5,... 75/‾ Values.

Age Group	1969 Population Males	1979 Population Males	Age Specific Growth Rate $_5r_x$	$\sum_{a=o}^{x-5} {_5r_a}$	2.5 $_5r_x$	$\exp\{\sum_{a=o}^{x-5} {_5r_a} + 2.5\,{_5r_x}\}$	No. of Deaths 1979 $_5D_x$	$k_x B_x\,{_5d_a}$	$_5\gamma_{x-5}$	N(X)
0-4	1 058 102	1 424 954	.02977				7739			75 054
5-9	916 599	1 249 662	.031	.02977		1.11322	803	894		57 490
10-14	714 707	1 053 099	.03876	.06077		1.17078	445	521		48 492
15-19	560 152	855 884	.04239	.09953		1.22815	427	524	[illegible]	39 545
20-24	428 015	642 723	.04066	.14192		1.27578	452	577	[illegible]	31 603
25-29	349 594	515 512	.03884	.18258		1.32270	566	749		25 385
30-34	280 948	406 221	.03687	.22142		1.36834	558	764		20 391
35-39	252 136	290 825	.01428	.25829		1.34175	578	776		16 449
40-44	193 936	262 019	.03009	.27257		1.41594	629	891		14 758
45-49	172 508	219 365	.02403	.30266		1.43725	638	917		12 113
50-54	132 466	183 285	.03247	.32669		1.50361	763	1147		10 141
55-59	114 669	141 067	.02072	.35916		1.50826	675	1018		7 918
60-64	102 466	107 932	.00520	.37988		1.48123	902	1336	1.001	6 493
65-69	74 611	100 112	.02940	.38508		1.58183	781	1235	1.0052	5 440
70-74	48 363	66 506	.03186	.41448		1.63905	869	1424	1.0052	3 967
75 +	83 109	87 947	.00566	.44634		1.58484	2576	4083		2 676

$_{30}d_{10}/_{20}d_{40}$ = .984 corresponding e(75) = 6.80

Table 3.3.2 (A) Life Table for the Total Male Population in Kenya 1979

[Bennett & Horiuchi]

Age Group	Probability of Surviving between Ages X and X+n $_nP_x$	Probability of dying between Ages X and X+n $_nQ_x$	Life Table Deaths Between Ages X and X+n $_nd_x$	ℓ_x	$_5L_x$	T_x	e_x
0-4	.88892	.11108	11 108	100 000	472 230	5 695 703	56.96
5-9	.98490	.0151	1 342	88 892	441 105	5 223 473	58.76
10-14	.98989	.01011	885	87 550	435 538	4 782 368	54.62
15-19	.98800	.012	1 041	86 665	430 725	4 346 830	50.16
20-24	.98417	.01583,	1 355	85 625	424 738	3 916 105	45.74
25-29	.97544	.02456	2 070	84 270	416 175	3 491 367	41.43
30-34	.96998	.03002	2 468	82 200	404 830	3 075 192	37.41
35-39	.96360	.0364	2 902	79 732	391 405	2 670 362	33.49
40-44	.95403	.04597	3 532	76 830	375 320	2 278 957	29.66
45-49	.94408	.05592	4 099	73 298	356 243	1 903 637	25.97
50-54	.91842	.08158	5 645	69 199	331 883	1 547 394	22.36
55-59	.91024	.08976	5 704	63 554	303 510	1 215 511	19.13
60-64	.85923	.14077	8 143	57 850	268 893	912 001	15.76
65-69	.84470	.1553	7 719	49 707	229 238	643 108	12.94
70-74	.79106	.20894	8 773	41 988	188 008	413 870	9.86
75 +				33 215	225 862	225 862	6.80

Table 3.3.2(B) Life Table for Males in Kenya 1979 [e(75)= 7.52]

Age	N(a)	$_5p_a$	$_5Q_a$	$_5d_a$	ℓ_a	$_5L_a$	T_a	e_a
0	76 274	.89069	.10931	10 931	100 000	472 673	5 732 306	57.32
5	58 541	.98517	.01483	1 321	89 069	442 043	5 259 633	59.05
10	49 392	.99007	.00993	871	87 748	436 563	4 817 590	54.90
15	40 286	.98553	.01447	1 257	86 877	431 243	4 381 027	50.43
20	32 120	.98443	.01557	1 333	85 620	424 768	3 949 784	46.13
25	25 803	.97583	.02417	2 037	84 287	416 343	3 525 016	41.82
30	20 735	.97047	.02953	2 429	82 250	405 178	3 108 673	37.80
35	16 735	.96420	.03580	2 858	79 821	391 960	2 703 495	33.87
40	15 024	.95486	.04514	3 474	76 963	376 130	2 311 535	30.03
45	12 342	.94511	.05489	4 034	73 489	357 360	1 935 405	26.34
50	10 344	.91996	.08004	5 559	69 455	333 378	1 578 045	22.72
55	8 090	.91214	.08786	5 614	63 896	305 445	1 244 667	19.48
60	6 653	.86251	.13749	8 013	58 282	271 378	939 222	16.12
65	5 591	.84882	.15118	7 600	50 269	232 345	667 844	13.29
70	4 097	.76910	.23090	9 852	42 669	188 715	435 499	10.21
75+	2 687				32 817	246 784	246 784	7.52

$$e(75)= M(75+)^{-1} \exp[-.0951\ M(75+)^{-1.4}\ r(75+)]$$

M(75)= Adjusted death rate. Mean diff.= .137 years.

Table 3.3.3 Estimation of e(75) and N(a) (a=0,5,...75) Values for the Total Female Population of Kenya 1979.

Age Group	1969 Population (Females)	1979 Population (Females)	Age Specific Growth Rate $_5r_a$	$\sum_{x=0}^{a-5} {_5r_x}$	$2.5\,{_5r_a}$	$\exp\{\sum_{x=0}^{a-5} {_5r_x} + 2.5\,{_5r_a}\}$	No. of Deaths 1979 Females $_5D_a$	k.Bx $_5d_a$	$_5\gamma_{x-5}$	N(a)
0-4	1 046 380	1 423 936	.03081				6939			49 808
5-9	893 359	1 246 983	.03335	.03081	.083375	1.12096	702	787		36 272
10-14	663 808	1 025 677	.04351	.06416	.10878	1.18879	357	424		30 055
15-19	544 847	889 316	.04899	.10767	.12248	1.25878	340	428		23 859
20-24	450 096	687 234	.04232	.15666	.1058	1.30013	341	443		18 375
25-29	411 245	542 233	.02765	.19898	.06913	1.30748	352	460		14 564
30-34	299 241	413 432	.03232	.22663	.0808	1.35993	316	430		12 355
35-39	264 819	325 951	.02077	.25895	.05193	1.36462	338	461		10 220
40-44	201 936	274 193	.03059	.27972	.07648	1.42789	269	384		8 891
45-49	163 852	222 363	.03053	.31031	.07633	1.47202	304	447		7 381
50-54	139 072	191 365	.03192	.34084	.0798	1.52294	350	533		6 054
55-59	102 235	134 776	.02763	.37276	.06908	1.55557	277	431		4 838
60-64	94 508	109 715	.01492	.40039	.0373	1.54912	482		1.0029	3 955
65-69	63 307	83 370	.02753	.41531			368		1.0051	3 205
70-74	45 987	62 651	.03092	.44284			413		1.0055	2 448
75 +	75 632	86 752	.01372	.47376			1576			1 713

$_5d_a = \frac{1}{k.B}\ {_5D_a} \exp\{\sum_{x=0}^{a-5} {_5r_x} + 2.5\ {_5r_a}\}$, $_{30}d_{10}\ /\ {_{20}d_{40}} = 1.474$ corresponding e(75) ≈ 6.15

Table 3.3.4(A) Construction of Life Table for Females in Kenya 1979

Age Group	$_5P_a$	$_5Q_a$	$_5d_a$	ℓ_a	$_5L_a$	T_a	e_a
0-4	.85952	.14048	14 048	100 000	464 880	5 573 275	55.73
5-9	.97896	.02104	1 808	85 952	425 240	5 108 395	59.43
10-14	.98677	.01323	1 114	84 144	417 935	4 683 155	55.66
15-19	.98391	.01609	1 336	83 030	411 810	4 265 220	51.37
20-24	.97938	.02062	1 684	81 694	404 260	3 853 410	47.17
25-29	.97410	.02590	2 072	80 010	394 870	3 449 150	43.11
30-34	.97228	.02772	2 161	77 938	384 288	3 054 280	39.19
35-39	.96516	.03484	2 640	75 777	372 285	2 669 992	35.23
40-44	.96736	.03264	2 387	73 137	359 718	2 297 707	31.42
45-49	.95548	.04452	3 150	70 750	345 875	1 937 989	27.39
50-54	.93743	.06257	4 230	67 600	327 425	1 592 114	23.55
55-59	.93360	.0614	3 891	63 370	307 123	1 264 689	19.96
60-64	.87313	.12687	7 546	59 479	278 530	957 566	16.10
65-69	.87652	.12348	6 412	51 933	243 635	679 036	13.08
70-74	.81675	.18325	8 342	45 521	206 750	435 401	9.56
75 +				37 179	228 651	228 651	6.15

Table 3.3.4(B) Life Table for Females in Kenya 1979 (e(75) = 6.86)

Age	N(a)	$_5P_a$	$_5Q_a$	$_5d_a$	ℓ_a	$_5L_a$	T_a	e_a
0	49 981	.85006	.14994	14 994	100 000	462 515	5 546 732	55.47
5	36 421	.97904	.02096	1 782	85 006	420 575	5 084 217	59.81
10	30 181	.98681	.01319	1 098	83 224	413 375	4 663 642	56.04
15	23 960	.98398	.01602	1 316	82 126	407 340	4 250 267	51.75
20	18 454	.97947	.02053	1 659	80 810	399 903	3 842 927	47.56
25	14 628	.97423	.02577	2 039	79 151	390 658	3 443 024	43.50
30	12 411	.97244	.02756	2 126	77 112	380 245	3 052 366	39.58
35	10 268	.96530	.03470	2 602	74 986	368 425	2 672 121	35.63
40	8 934	.96753	.03247	2 350	72 384	356 045	2 303 696	31.83
45	7 418	.95574	.04426	3 100	70 034	342 420	1 947 651	27.81
50	6 086	.93770	.06230	4 170	66 934	324 245	1 605 231	23.98
55	4 865	.93905	.06095	3 825	62 764	304 258	1 280 986	20.41
60	3 979	.87382	.12618	7 437	58 939	276 103	976 728	16.57
65	3 227	.87731	.12269	6 319	51 502	241 713	700 625	13.60
70	2 467	.81803	.18197	8 222	45 183	205 360	458 912	10.16
75	1 729				36 961	253 552	253 552	6.86

$e(75) = M(75)^{-1} \exp\{-.0951\, M(75+)^{-1.4}\, r(75)\}$; $M(75)$ = Adjusted mortality (death) rate.

Mean = .40 years.

Table 3.3.5 Ratio of Life Expectancy at Various Ages: Males.

Start of Age internal (1)	e_x^o [Estimated] (2)	e_x^o [level 15 West Model] (3)	Ratio (4) = (2)/(3)
0	56.96	51.831	1.099
5	58.76	56.294	1.044
10	54.62	52.162	1.047
15	50.16	47.749	1.050
20	45.74	43.562	1.050
25	41.43	39.616	1.046
30	37.41	35.652	1.049
35	33.49	31.713	1.056
40	29.66	27.844	1.065
45	25.97	24.096	1.078
50	22.36	20.484	1.092
55	19.13	17.095	1.119
60	15.76	13.935	1.131
65	12.94	11.105	1.165
70	9.86	8.585	1.149
75	6.80	6.409	1.061

Table 3.3.6 Ratio of Life Expectancy at Various Ages: Females

Start of Age Interval (1)	e_x^o [Estimated] (2)	e_x^o [level 15 West Model] (3)	Ratio $(4)={}^{(2)}/_{(3)}$
0	55.73	55.00	1.013
5	59.43	58.698	1.012
10	55.66	54.596	1.019
15	51.37	50.238	1.023
20	47.17	46.084	1.024
25	43.11	42.096	1.024
30	39.19	38.149	1.027
35	35.23	34.229	1.029
40	31.42	30.324	1.036
45	27.39	26.429	1.036
50	23.55	22.576	1.043
55	19.96	18.901	1.056
60	16.10	15.404	1.045
65	13.08	12.241	1.069
70	9.56	9.391	1.018
75	6.15	6.96	.884

Fig. 3.3.1 RATIO, LIFE EXPECTANCY USING INCOMPLETE DEATH REGISTRATION DATA METHOD TO LIFE EXPECTANCY WEST LEVEL 15, KENYA MALES : 1979

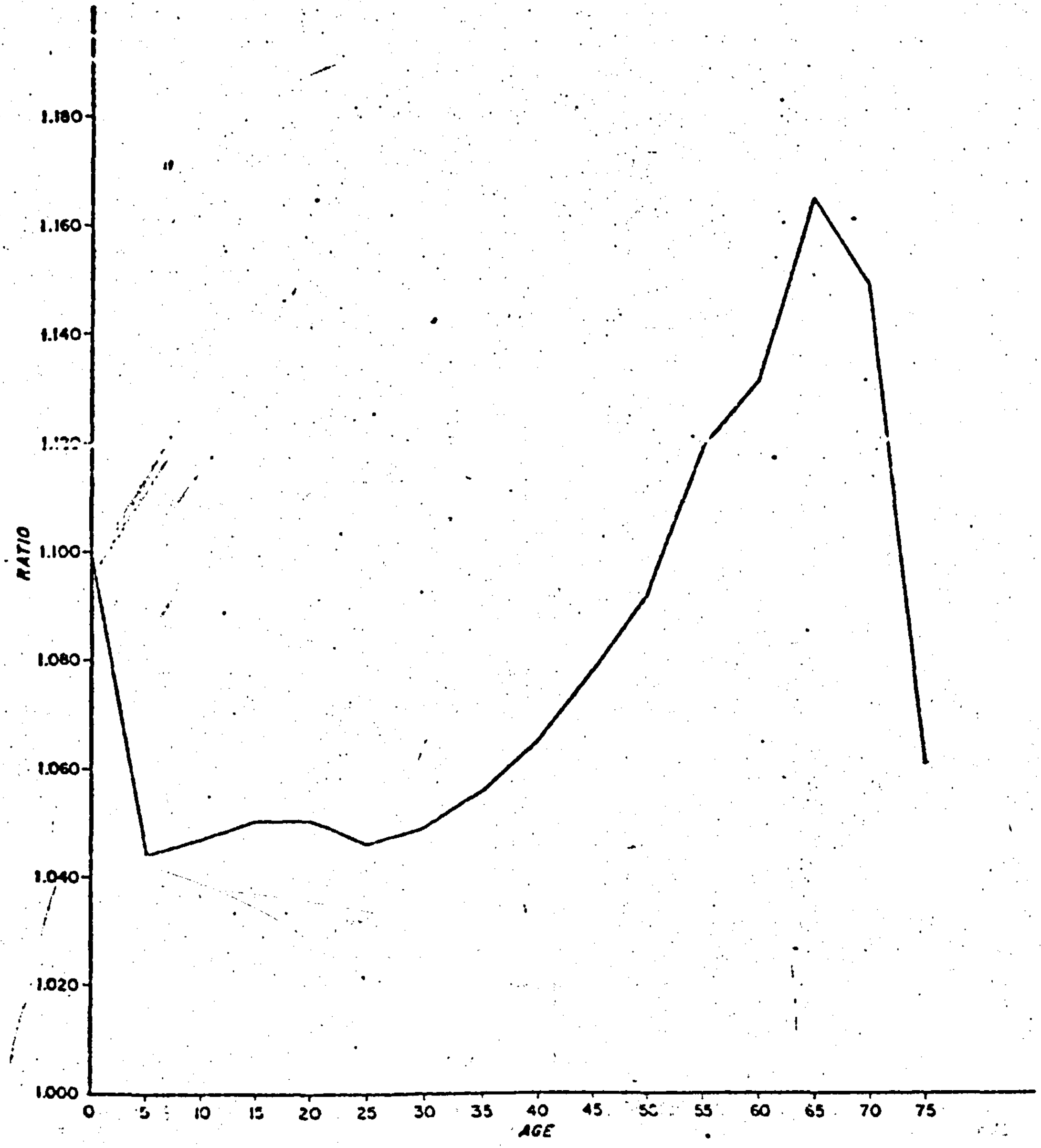
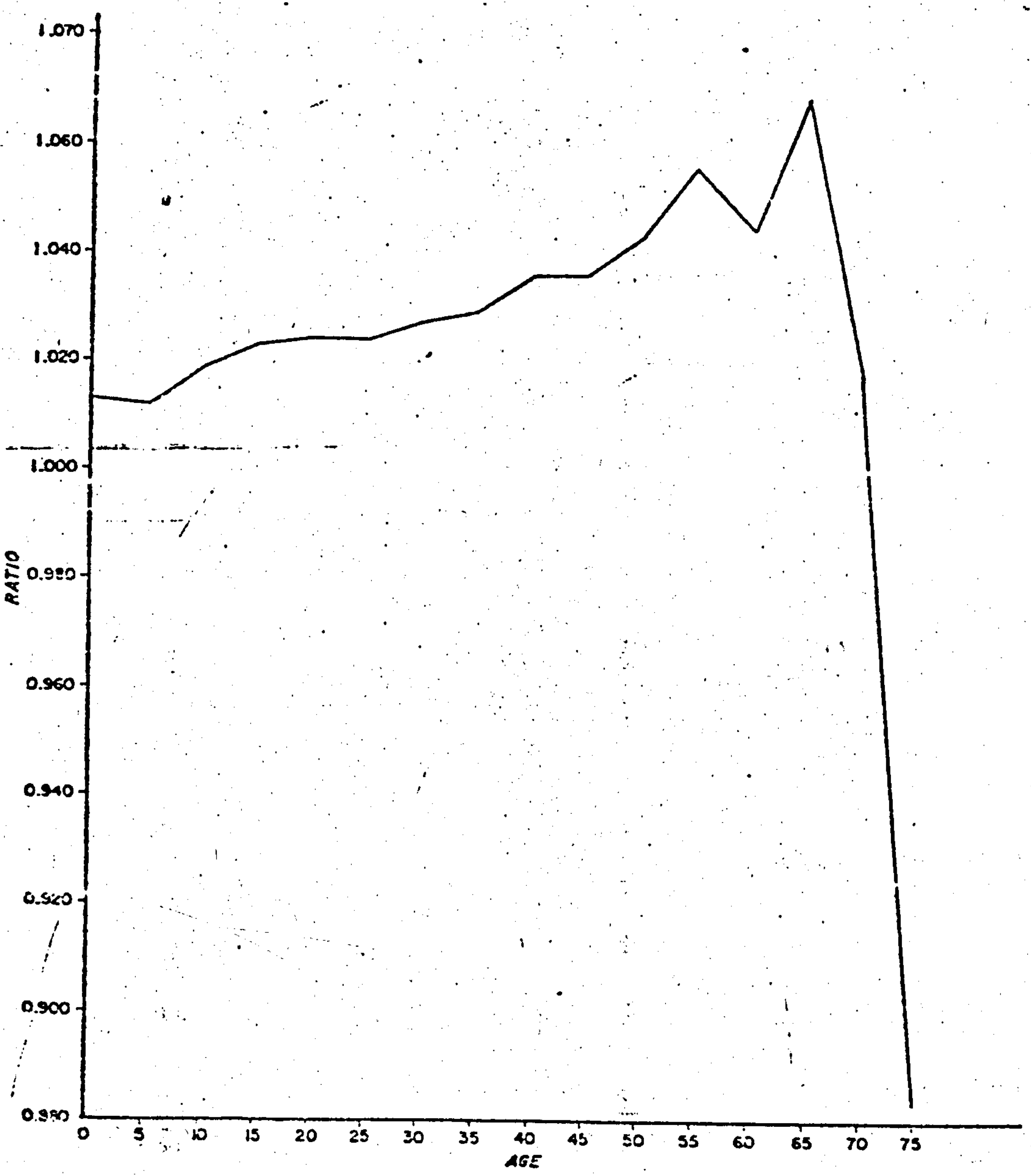


Fig. 3.3.2 RATIO, LIFE EXPECTANCY USING INCOMPLETE DEATH REGISTRATION DATA METHOD TO LIFE EXPECTANCY WEST LEVEL 15, KENYA 1979 : FEMALES



3.4 APPLICATION OF METHOD III: CONSTRUCTION OF LIFE TABLES FROM TWO SUCCESSIVE CENSUSES DATA ONLY:

Preston[11] (1981) proposed a method to estimate the level of adult mortality to which a population has been subject during a given intercensal period from the age distributions produced by two consecutive censuses. As any other method that estimates mortality on the basis of intercensal comparisons, Preston's method requires that the population be closed (that is, not subject to migration) and that the completeness of coverage attained by each of the censuses being compared be the same.

In discrete terms, using five-year age groups, the basic equation proposed by Preston is

$$e_x = \frac{\sum_{y=x}^{\infty} {}_5N_y \exp\{5.0 \sum_{a=x}^{y-5} {}_5r_a + 2.5 \; {}_5r_y\}}{N(x)} \quad \ldots\ldots \quad (3.4.1)$$

where ${}_5N_y$ is the mid-period population in age group y to y+4, ${}_5r_y$ is the intercensal growth rate of age group y to y+4, and N(x), the mid-period number of persons aged 'x', is estimated by

$$N(x) = \frac{{}_5N_x + {}_5N_{x-5}}{10} \quad \ldots\ldots \quad (3.4.2)$$

A preferable procedure, however, is to derive N(x) in a fashion analogous to the derivation of the numerator in the estimation of ^{e}x.

Therefore

$$N(x) = \frac{5^{N}x\ e^{2.5}\ 5^{r}x + 5^{N}x{-}5\ e^{-2.5}\ 5^{r}x{-}5}{10} \quad \ldots(3.4.3)$$

The age specific growth rate $5^{r}y$ is obtained by

$$5^{r}y = \frac{1}{t_2-t_1}\ \ell n \left[\frac{5^{N}y\ (t_2)}{5^{N}y\ (t_1)}\right]$$

Where t_1 and t_2 are the periods when the censuses were conducted. In this study $t_2-t_1 = 10$ years.

If equation (3.4.3) is adopted for N(x), a life table pertaining to all ages can be constructed in one pass through the data. The N(x) estimate is clearly analogous to ℓ_x in a life table, and is derived by (in effect) averaging $5^{L}x$ in the two age intervals centered on x. In other words, it is not necessary to recompute a new life table for each initial age; since all elements ($n^{L}x$ and ℓ_x) in the life table beginning with age x+5 would differ from age - corresponding elements in the lift table beginning with age x by the factor $e^{-5}\ 5^{r}x$, life expectancy estimates, which are invariant to the scale of $5^{L}x$ and ℓ_x, are unaffected by the choice of the initial age.

In summary Method III consists of the following steps:

Step-One:

From the two censuses, compute $_5N_y$, the mean number of persons within the period of the two censuses in the age group 'y' to 'y+5'.

Where

$$_5N_y = \frac{_5N_y(t_1) + {_5N_y}(t_2)}{2}$$

Step-Two:

Compute $_5r_y$, the annual age specific growth rate between the periods.

Step-Three:

Compute, $R_{(y)}$, sum of growth rates from age 5 to mid-point

$$R_{(y)} = 5.\sum_{a=5}^{y-5} {_5r_a} + 2.5\ {_5r_y}$$

$Ro = -2.5\,_5r_0$ and $R_5 = 2.5\ _5r_5$. The mid-point of the open interval A and above is A+2.5.

Step-Four:

Compute $_nL_y$, person years lived during the interval in life table.

$$_nL_y = {_5N_y}.\ e^{R(y)}$$

Step-Five:

Compute T_y, person years lived above age y in life table.

$$T_y = \sum_{y}^{\infty} {}_5L_y$$

Step-Six:

Compute number surviving to age y in life table:

$$\ell_y = ({}_5L_y + {}_5L_{y-5}) / 10$$

Step-Seven:

Compute life expectancy at age y,

$$e^{o}_y = \frac{T_y}{\ell_y}$$

We note from Step-Three above that the "inflation factors" in the estimation of life expectancy are given by

$$R(y) = 2.5 \; {}_5r_y + 5.0 \sum_{a=5}^{y-5} {}_5r_a.$$

For the open interval, age A and above, in a 5 year age interval, the mid-point is given by A+2.5 and we realise that, the growth rate of the open interval is used to estimate R(A). Hill and Zlotnik[12] (1982) for reasons explained in Method III Chapter II, introduced a different procedure of estimating R(A) without the use of the growth rate of the uppermost age interval.

They proposed the formula:

$$R(A) = \rho(A) + 5.0 \sum_{a=0}^{A-5} 5^{r}a$$

Where $\rho(A) = a(A) + b(A)\, r(10+) + C(A)\, \ell n \left[N(45+)/N(10+) \right]$

And sets of the coefficients a(A), b(A) and C(A) are given for different truncation ages in table A.2 in the appendix. Thus for A= 75; we have

$$R(75) = \rho(75) + 5.0 \sum_{a=0}^{70} 5^{r}y$$

In this study, the intercensal-based method of constructing life tables will be referred to as Method III (a) if the open interval is treated as suggested by Preston. If it is estimated by using the Hill and Zlotnik modification of the Preston method, then the method will be referred to as Method III (b).

Table 3.4.1 and 3.4.2 show the results obtained when Method III (a) discussed above is applied to the 1969-1979 Kenya censuses data. Table 3.4.3 and 3.4.4 also show the estimates obtained when Method III (b) is applied to the 1969 - 1979 Kenya Censuses data.

Comparing table 3.4.1 and 3.4.3 for males, and table 3.4.2 and 3.4.4 for females shows that the life expectancy estimates obtained by Method III (a) are relatively lower (compared) to the estimates obtained by Method III (b). The range of the difference for both males and females is

.83 years, while the mean difference of the ^{e}x estimates is .67 years for males and .65 years for females. It is further observed that for males, the difference <u>decreases</u> as one goes downward in the age distribution except at age 75. For females, the pattern is clear only from age 25 onwards. In other words, except at age 75, the difference of the corresponding ^{e}x estimates declines with decrease in age upto age 25.

Since the mean difference of the life expectancy estimates obtained by Methods (a) and (b) is less than .7 years for both males and females, and the absolute difference between ages (5 and 50), the ages at which the Preston method is most applicable is less than .75 years, we see that the Hill and Zlotnik modification of the treatment of the open interval in the Preston cenus-based method does not produce very significant differences in the sets of the life expectancy estimates. If any thing, the difference declines with decrease in age. Therefore the treatment of the open interval does not affect much the life expectancy estimates at lower ages.

Both life expectancy estimates displayed in Table 3.4.1, 3.4.2, 3.4.3 and 3.4.4 appear acceptable (they decline steadily as age increases). However, their validity cannot be judged directly from their values. That is because, the estimates obtained by these method(s) are vulnerable or sensitive to:

(i) errors in estimated growth rates - mainly due to differential coverage between the two censuses;

(ii) net intercensal migration;

and (iii) errors in age reporting.

While the effect of errors due to net intercensal migration may be assumed to be negligible in Kenya, the effect of errors due to differential coverage between the two censuses and errors in age reporting, cannot be assumed to be negligible.

In order therefore to study the validity of the e_x estimates in table 3.4.1, 3.4.2, 3.4.3 and 3.4.4 with respect to the two types of errors we shall use the mortality experience summarized in model life tables as a standard against which to compare the estimated set of life expectancies.

Models may be useful in that they provide a very clear indication of how life expectancy by age is expected to change as mortality levels change. More so, the changes in life expectancy by age are, to a close approximation, equiproportionate between ages 5 and 50 (but not outside this range). Thus, the ratio of the estimated set of life expectancies by age to the set pertaining to a particular model level should be nearly level if there is no error due to age misreporting. On the other hand, if the ratios deviate from near level with a strong age trend in ratio, then there is error due to differential coverage of the two censuses. If there are deviations from near level and there is no strong age trend in ratios, then the deviations will be said to be only due to errors in age reporting.

In this study, we have selected model "West" level 15 as our standard model. Table 3.4.5 and 3.4.6 are displays of the life expectancy estimates, corresponding Model West level 15 values and their ratios for males and females respectively. And figure 3.4.1 and 3.4.2 show the graphical display of the ratios for males and females respectively. Figure 3.4.1 reveals that for males, for all ages approximately less than 34 years, the ratios are higher than the mean ratios. After age 34 onwards, the ratios are higher than the Mean Values. (Mean of the ratios between ages '5' and '50'). The ratios are not near level and they show a clear pattern. The ratios increase as age increases from age 10 onwards. This therefore suggests the presence of differential coverage in the two censuses (1969 - 1979) and the existence of errors in age reporting.

For females, the sequence of the ratios as displayed in figure 3.4.2 reveals a pattern which is quite different from that for males. Ratios of the estimated life expectancies to the set pertaining to Model "West" level 15 show great deviations from the mean values and there is a strong age trend in the ratios, with the trend declining from age 5 to age 25 and then increasing with increase in age afterwards. The ratios are less than the mean values between ages say '14' years and '35' years for the Preston life expectancy estimates, and between ages '13' years and '35' years for the Hill and Zlotnik life expectancy estimates. At all the other ages, the ratios are higher than the mean values.

Figure 3.4.2 suggests that as for males, the life expectancy estimates for females obtained by these method are affected by errors due to differential coverage in the two censuses and errors in age reporting. The pattern of the ratios for males and females suggests that the two types of errors are more prevalent among females to males.

Examination of the ℓ_y values for males shows that the ℓ_y values does not suggest any erratic behaviour, while the ℓ_y values for females shows some erratic behaviour at younger age groups. This, further suggests that for females, errors in age reporting affect the e_y values through the ℓ_y estimates. The case for males is however not clear.

The life expectancy estimates provided by Methods III (a) and (b) are both affected by age misreporting and differential coverage in the two censuses. Therefore in order to use these life expectancy estimates, one should smoothen them. There are several smoothing procedures available. The simplest is, since changes in life expectancy are linear to a close approximation between age 5 and 50, one may simply take averages of 3 or 5 observations centered on the age for which an estimate is being made. Otherwise, he or she can resort to model life tables.

Table 3.4.1 Life Table for the Total Male Population in Kenya Derived Using the Census Based Method (1969 - 1979)

Start of Age Interval (y)	Mean No. of Persons 1969-1979 $_5N_y$	Annual Age Specific Growth Rate $_5r_y$	$5.\sum_{a=5}^{y-5} {_5r_a}$ (a≥10	$2.5\ _5r_y$	$R(y)=5.\sum_{a=5}^{y-5} {_5r_a} + 2.5\ _5r_y)$	$_5L_y={_5N_y}.e^{R(y)}$	$T_y=\sum_y^\infty {_5L_y}$	$\ell_y=({_5l_y}+{_5L_{y=5}})/10$	$e_y=\frac{T_y}{\ell_y}$
0	1 241 483	.02977			-.074425	1 152 440	13890380		
5	1 083 131	.031		.0775	.0775	1 170 412	12737940	232 285	54.84
10	883 903	.03876	.155	.09690	.2519	1 137 112	11567528	230 752	50.13
15	708 018	.04239	.3488	.10598	.45478	1 115 714	10430416	225 283	46.30
20	535 369	.04066	.5608	.10165	.66245	1 038 369	9314702	215 408	43.24
25	432 553	.03884	.7641	.0971	.86120	1 023 420	8276333	206 179	40.14
30	343 585	.03687	.9583	.09218	1.05048	982 317	7252913	200 574	36.16
35	271 481	.01428	1.14265	.03570	1.17835	882 044	6270596	186 436	33.63
40	227 978	.03009	1.21405	.07523	1.28928	827 599	5388552	170 964	31.52
45	195 937	.02403	1.3645	.06008	1.42458	814 336	4560953	164 194	27.78
50	157 876	.03247	1.4847	.08118	1.56588	755 734	3746617	157 007	23.86
55	127 868	.02072	1.6471	.0518	1.6989	699 173	2990883	145 491	20.56
60	105 199	.00520	1.7507	.01300	1.7637	613 729	2291710	131 290	17.46
65	87 362	.02940	1.7767	.07350	1.8502	555 718	1677981	116 945	14.35
70	57 435	.03186	1.9237	.07965	2.00335	425 815	1122263	98 153	11.43
75	85 528	.00566	2.083	.01415	2.09715	696 448	696448	112 226	6.21

$R(o) = -2.5\ _5r_o$

Table 3.4.2 Life Table for the Total Female Population in Kenya Derived Using the Census Based Method (1969 - 1979)

Start of Age Interval (y)	Mean No. of Persons 1969-1979 $_5N_y$	Annual Age Specific Growth Rate $_5r_y$	$5.\sum_{a=5}^{y-5} {_5r_a}$	$2.5\,{_5r_y}$	$R(y)=(5.\sum_{a=5}^{y-5} {_5r_a} + 2.5\,{_5r_y})$	$_5L_y={_5N_y}.e^{R(y)}$	$T_y=\sum_{y}^{\infty} {_5L_y}$	$\ell_y=({_5L_y}+{_5L_{y-5}})/10$	$e_y = \frac{T}{\ell}$
0	1 235 158	.03081			-.077025	1 143 592			
5	1 070 171	.03335		.083375	.083375	1 163 222	13 558 851	230 681	58.78
10	844 743	.04351	.16675	.108775	.27553	1 112 720	12 395 629	227 594	54.46
15	717 082	.04899	.3843	.122475	.50678	1 190 312	11 282 909	230 303	48.99
20	568 665	.04232	.62925	.1058	.73505	1 186 000	10 092 597	237 631	42.47
25	476 739	.02765	.84085	.06913	.90998	1 184 350	8 906 597	237 035	37.58
30	356 337	.03232	.9791	.0808	1.0599	1 028 418	7 722 247	221 277	34.90
35	295 385	.02077	1.1407	.05193	1.19263	973 511	6 693 829	200 193	33.44
40	238 065	.03059	1.24455	.07648	1.32103	892 096	5 720 318	186 561	30.66
45	193 108	.03053	1.3975	.07633	1.47383	843 095	4 828 222	173 519	27.83
50	165 219	.03192	1.55015	.0798	1.62995	843 215	3 985 127	168 631	23.63
55	118 506	.02763	1.70975	.06908	1.77883	701 902	3 141 912	154 512	20.33
60	102 112	.01492	1.8479	.0373	1.8852	672 680	2 440 010	137 458	17.75
65	73 339	.02753	1.9225	.06883	1.99133	537 228	1 767 330	120 991	14.61
70	54 319	.03092	2.06015	.07731	2.13745	460 505	1 230 102	99 773	12.33
75	81 192	.01372	2.21475	.0343	2.24905	769 597	769 597	123 010	6.23

$R(o) = -2.5\,{_5r_o}$.

Table 3.4.3 Life Table for the Total Male Population in Kenya Derived Using the Census Based Method (1969 - 1979)

Start of Age Interval (y)	Mean No. of Persons 1969-1979 $_5N_y$	Annual Age Specific Growth Rate $_5r_y$	$5.\sum_{a=0}^{y-5} {}_5r_a$ $(y \geq 5)$	$2.5\ {}_5r_y$	$R(y)=(2.5\,{}_5r_y + 5\sum_{a=0}^{y-5} {}_5r_a)$	$_5L^*_y = {}_5N_y . e^{R(y)}$	$T_y = (L_A + \sum_{a=y}^{A-5} {}_5L_a)$	$\ell^*_y = \frac{({}_5L_{y-5} + {}_5L_y)}{10}$	$e_y = \frac{T_y}{\ell_y}$
0	1 241 483	.02977		.07443	.07443	1 337 412	16 253 011		
5	1 083 131	.031	.14885	.0775	.22635	1 358 262	14 915 599	269 567	55.33
10	883 903	.03876	.30385	.09690	.40075	1 319 618	13 557 337	267 788	50.63
15	708 013	.04239	.49765	.10598	.60363	1 294 784	12 237 719	261 440	46.81
20	535 369	.04066	.7096	.10165	.81125	1 204 966	10 942 935	249 975	43.78
25	432 553	.03884	.9129	.0971	1.010	1 187 618	9 737 969	239 258	40.70
30	343 585	.03687	1.1071	.09218	1.19928	1 139 921	8 550 351	232 754	36.74
35	271 481	.01428	1.29145	.03570	1.32715	1 023 560	7 410 430	216 348	34.25
40	227 978	.03009	1.36285	.07523	1.43808	960 380	6 386 870	198 394	32.19
45	195 937	.02403	1.5133	.06008	1.57338	944 989	5 426 490	190 537	28.48
50	157 876	.03247	1.63345	.08118	1.71463	876 941	4 481 501	182 193	24.60
55	127 868	.02072	1.7958	.05180	1.8476	811 268	3 604 560	168 821	21.35
60	105 199	.00520	1.8994	.01300	1.9124	712 125	2 793 292	152 339	18.34
65	87 362	.02940	1.9254	.07350	1.9989	644 813	2 081 167	135 694	15.34
70	57 435	.03186	2.0724	.07965	2.15205	494 083	1 436 354	113 890	12.61
75	85 528	.00566	2.2317	.01415	2.39945	942 271	942 271	143 635	6.56

$R(o) : 2.5\ {}_5r_o$ $N(45+)/N(10+) = .19365$ $r(10+) = .03409$ $R(75) = \rho(75) + 5\sum_{y=o}^{A-5} {}_5r_y$

Table 3.4.4 Life Table for the Total Female Population in Kenya Derived Using the Census Based Method (1969 - 1979)

Start of Age Interval (y)	Mean No. of Persons 1969-1979 ${}_5N_y$	Annual Age Specific Growth Rate ${}_5r_y$	$5.\sum_{a=o}^{y-5}{}_5r_a$	$2.5\ {}_5r_y$	$R(y)=(2.5\,{}_5r_y+\sum_{a=o}^{y-5}{}_5r_a)$	${}_5L_y={}_5N_y\,e^{R(y)}$	$T_y={}_{\omega-A}L_A+\sum_{a=y}^{A-5}{}_5L_a$	$(\ell_y=\frac{({}_5L_y+{}_5L_{y-5})}{10}$	$e_y=\frac{T_y}{\ell_y}$
0	1 235 158	.03081		.077025	.077025	1 334 056	17 288 910		
5	1 070 171	.03335	.15405	.083375	.237425	1 356 955	15 954 854	269 101	59.29
10	844 743	.04351	.3208	.108775	.429575	1 298 036	14 597 899	265 499	54.98
15	717 082	.04899	.53835	.122475	.660825	1 388 550	13 299 863	268 659	49.50
20	568 665	.04232	.7833	.10580	.8891	1 383 527	11 911 313	277 208	42.97
25	476 739	.02765	.9949	.06913	1.06403	1 381 602	10 527 786	276 513	38.07
30	356 337	.03232	1.13315	.08080	1.21395	1 199 700	9 146 184	258 130	35.43
35	295 385	.02077	1.29475	.05193	1.34668	1 135 649	7 946 484	233 535	34.03
40	238 065	.03059	1.39860	.07648	1.47508	1 040 674	6 810 835	217 632	31.30
45	193 108	.03053	1.55155	.07633	1.62788	983 512	5 770 161	202 419	28.51
50	165 219	.03192	1.7042	.07980	1.784	983 652	4 786 649	196 716	24.33
55	118 506	.02763	1.8638	.06908	1.93288	818 803	3 802 997	180 246	21.10
60	102 112	.01492	2.00195	.03730	2.03925	784 715	2 984 194	160 352	18.61
65	73 339	.02753	2.07655	.06883	2.14538	626 703	2 199 479	141 142	15.58
70	54 319	.03092	2.2142	.07731	2.29151	537 207	1 572 776	116 391	13.51
75	81 192	.01372	2.3688	.03429	2.54589	1 035 569	1 035 569	157 278	6.58

N(45+)/N10+)= .18386 R(o)= $2.5\,{}_5r_o$, r(10+) = .03606 ρ(75)= .17709 R(75)= ρ(75)+.5 $\sum_{y=0}^{70}{}_5r_y$.

Table 3.4.5 Ratio of Life Expectancy at Various Ages: Males

Age (1)	$\overset{o}{e}_x$ [By Preston Method] (2)	$\overset{o}{e}_x$ [By Preston Modified] (3)	$\overset{o}{e}_x$ [Level 15, West Model] (4)	Ratio (5) = (2)/(4)	Ratio (6) = (3)/(4)
5	54.84	55.33	56.294	.974	.983
10	50.13	50.63	52.162	.961	.971
15	46.30	46.81	47.749	.970	.980
20	43.24	43.78	43.562	.993	1.005
25	40.14	40.70	39.616	1.013	1.027
30	36.16	36.74	35.652	1.014	1.031
35	33.63	34.25	31.713	1.060	1.080
40	31.52	32.19	27.844	1.132	1.156
45	27.78	28.48	24.096	1.153	1.182
50	23.86	24.60	20.484	1.165	1.201
55	20.56	21.35	17.095	1.203	1.249
60	17.46	18.34	13.935	1.253	1.316
65	14.35	15.34	11.105	1.292	1.381
70	11.43	12.61	8.585	1.331	1.469
75	6.21	6.56	6.409	.969	1.024

Fig. 3.4.1 RATIO, LIFE EXPECTANCY USING CENSUS BASED METHOD TO LIFE EXPECTANCY WEST LEVEL 15, KENYA MALES : 1969–1979

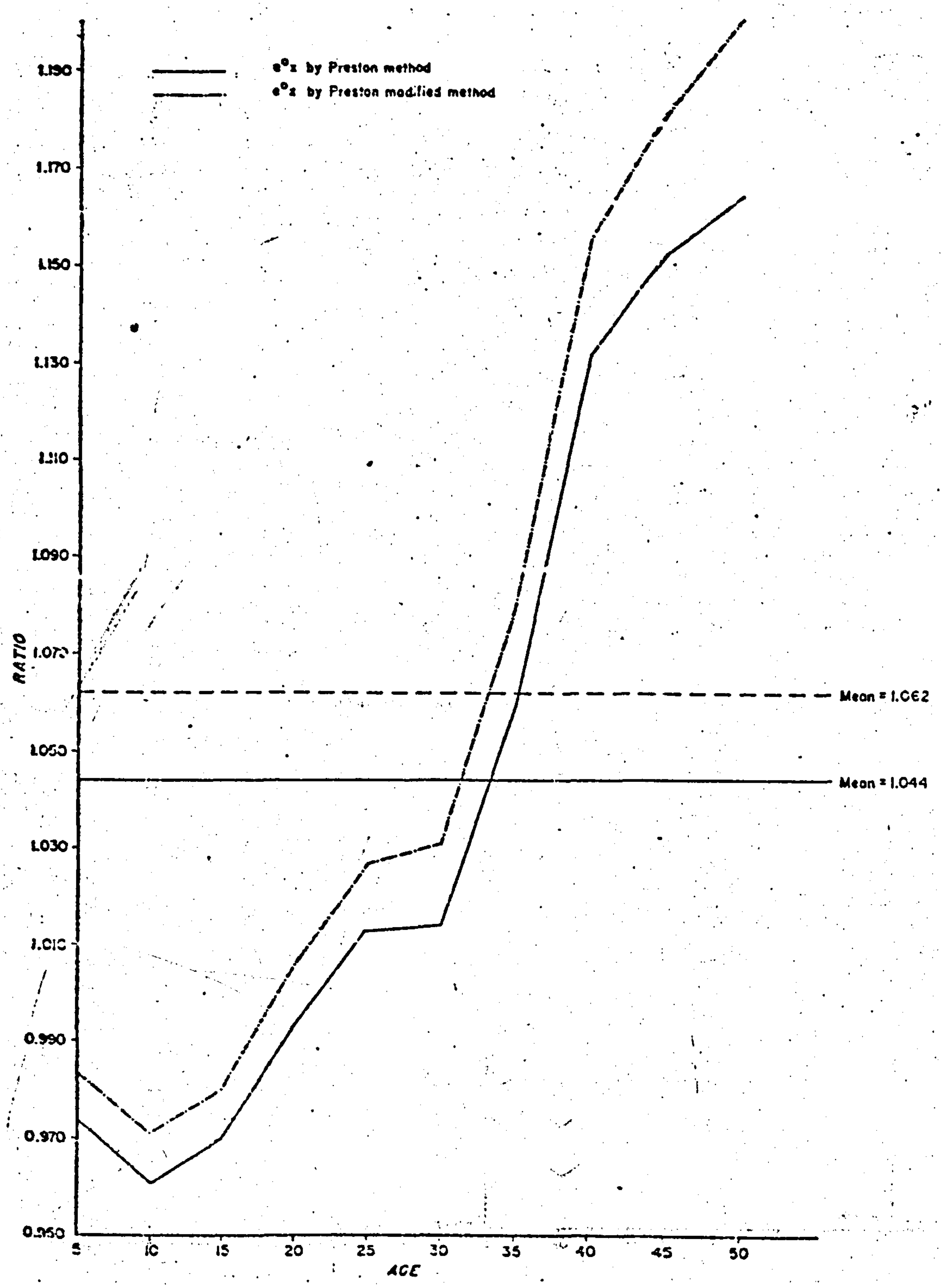
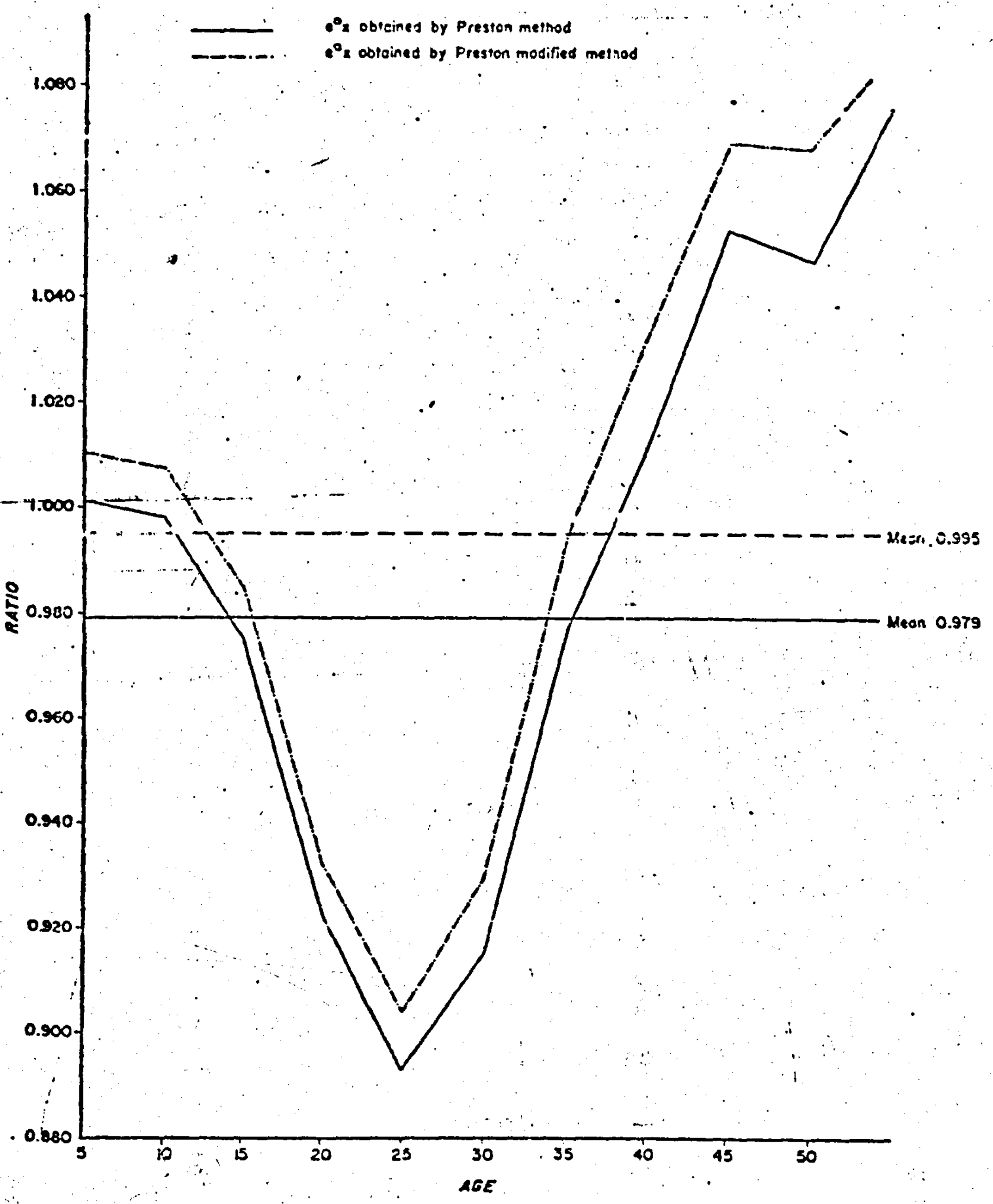


Table 3.4.6 Ratio of Life Expectancy at Various Ages: (Females)

Age (1)	e_x^o [By Preston Method] (2)	e_x^o [By Preston Modified Method] (3)	e_x^o(level 15, West Model) (4)	Ratio $(5)=\frac{(2)}{(4)}$	Ratio $(6)=\frac{(3)}{(4)}$
5	58.78	59.29	58.698	1.001	1.010
10	54.46	54.98	54.596	.998	1.007
15	48.99	49.50	50.238	.975	.985
20	42.47	42.97	46.084	.922	.932
25	37.58	38.07	42.096	.893	.904
30	34.90	35.43	38.149	.915	.929
35	33.44	34.03	34.229	.977	.994
40	30.66	31.30	30.324	1.011	1.032
45	27.83	28.51	26.429	1.053	1.079
50	23.63	24.33	22.576	1.047	1.078
55	20.33	21.10	18.901	1.076	1.116
60	17.75	18.61	15.404	1.152	1.208
65	14.61	15.58	12.241	1.194	1.273
70	12.33	13.51	9.391	1.313	1.439
75	6.23	6.58	6.960	.903	.945

Fig.3.4.2 RATIO, LIFE EXPECTANCY USING CENSUS-BASED METHOD TO LIFE EXPECTANCY, WEST LEVEL 15, KENYA FEMALES 1969—1979.



3.5 COMPARISON OF THE LIFE EXPECTANCY ESTIMATES

In Section 3.3, Model "West" level 15 set of life expectancy values were used to study the internal consistency of the life expectancy obtained using the incomplete death registration data Method, (Method II). In Section 3.4, model "West" level 15 set of life expectancy values were also used to study the validity of the life expectancy estimates obtained using the Census based Method, [Methods III (a) and (b)].

It was found in Section 3.3 that the life expectancy estimates obtained by Method II were affected by age misreporting. In Section 3.4, it was further found that apart from being affected by age misreporting, the life expectancy estimates obtained by Method III (Census based Method) were affected by errors due to differential coverage of the Censuses (1969-1979).

In this Section, I would now like to compare the life expectancy estimates due to Methods II and III [(a) and (b)] with those values in the 1979 Kenya Model life tables to see how the estimates agree with each other.

Table 3.5.1 and 3.5.2 show the life expectancy estimates by Methods II and III (a and b), the corresponding 1979 Kenya Nation life table life expectancy values and the ratios of the estimated values to the set pertaining to 1979 Kenya National Model life tables for males and females respectively. Table 3.5.1 shows that for males, life expectancy estimates by Method II are relatively higher than the 1979 Kenya Model life table values since the ratio is greater than unity at all ages. It is further observed that between age 5 and 30, the ratios of the life expectancy estimates due to Method II to the "Standard" life expectancy values are relatively higher compared to the ratios of the life expectancy estimates due to Method III (a (a and b) to the set pertaining to the 1979 Kenya National life tables, referred to as the "Standard". Afterwards, the pattern of the ratios changes.

Ratios of the life expectancy estimates due to Method III (a) to the set pertaining to the 1979 Kenya National life tables, and the ratios of the life expectancy estimates due to Method III (b) to the Set Pertaining to the 1979 Kenya National Model life tables indicates that, Method III (b) estimates are relatively higher compared to Method III (a) estimates. Further it is observed that both Methods III (a) and (b) give relatively lower life expectancy estimates from age 5 up to age 30. From age 35 onwards (except at age 75), the "Standard" values are relatively lower than the estimated values.

Considering deviations of the ratios from unity, it is observed that, the absolute deviations of the ratios of the life expectancy estimates due to Method II to the "Standard" life table values for Kenya are smaller relative to the ratios of the life expectancy estimates due to Method III (a) and (b) to the "Standard" life table values. Further it is observed that for ages less than 35 years, Method III (b) gives better life expectancy estimates than Method III (a). Afterwards, Method III (a) gives life expectancy estimates which agree relatively better with the "Standard" values to the estimates obtained by Method III (b).

For females, table 3.5.2 shows that unlike in the case for males, the ratios of the estimated life expectancy estimates due to Method II to the set pertaining to the "Standard" life table are greater than unity from age 30 onwards (except at age 75). From age 5 up to age 35, the ratios of the life expectancy estimates due to Method II to the corresponding values in the "Standard" life table are higher relative to the ratios of the life expectancy estimates obtained by Method III (a and b) to the "Standard" values. Afterwards, the pattern changes. Further it is observed that for Method III (a and b), the ratios reveal that from age 5 up to age 40, Method III (b) gives life expectancy values which relatively agree better with the "Standard" values compared with the estimates due to

Method III (a). Above age 40, Method III (a) gives better values compared to Method III (b) as deviations of the ratios from unity is small for the life expectancy estimates due to Method III (a) compared to those obtained by Method III (b).

As for males, the ratios in table 3.5.2 suggest that the life expectancy estimates due to Method II agree relatively better with the "Standard" 1979 life expectancy values for females compared with the life expectancy values due to Method III (a) and (b). For this reason, and on the assumption that the 1979 Kenya Model life tables are accurate and correct, we can conclude that the mortality estimates derived by Method II due to Bennett and Horiuchi are good. On the basis of this conclusion, we expect the cause of death life tables which will be derived from the results obtained by Method II by the single and multiple decrement methods in the next chapter to be fairly good in the cause of death analysis.

Table 3.5.1 e(x) - x=o,.... 75 Values as obtained by various Methods (Males)

Age Group	Bennett & Horiuchi Method II	Preston Method III (a)	Hill & Hania Modification of Preston Method III(b)	Model life Table (1979) (Observed)	II÷OBS	III(a) ÷ OBS	III(b) ÷ OBS
0-4	56.96			52.6	1.083		
5-9	58.76	54.80	55.33	57.6	1.020	.951	.961
10-14	54.62	50.09	50.63	53.5	1.021	.936	.946
15-19	50.16	46.26	46.81	49.1	1.022	.942	.953
20-24	45.74	43.19	43.78	45.0	1.016	.960	.973
25-29	41.43	40.11	40.70	41.2	1.006	.974	.988
30-34	37.41	36.16	36.74	37.3	1.003	.969	.985
35-39	33.49	33.63	34.25	33.3	1.006	1.010	1.029
40-44	29.66	31.52	32.19	29.4	1.009	1.072	1.095
45-49	25.97	27.78	28.48	25.5	1.018	1.089	1.117
50-54	22.36	23.86	24.60	21.7	1.030	1.100	1.134
55-59	19.13	20.56	21.35	18.0	1.063	1.142	1.186
60-64	15.76	17.46	18.34	14.6	1.079	1.196	1.256
65-69	12.94	14.35	15.34	11.5	1.125	1.248	1.334
70-74	9.86	11.43	12.61	8.8	1.12	1.299	1.433
75 +	6.80	6.21	6.56	6.7	1.015	.927	.979

Table 3.5.2 e(x) Values (x=0,5,10,.... 75) as Obtained by Various Methods of Constructing Life Tables (Females)

Age Group	Bennett and Horiuchi Method II	Preston Method III (a)	Hill & Hania Modifications of Preston Method III (b)	Model Life Table (1979) (Observed)		II ÷ OBS	III ÷ OBS (a)	III÷OBS (b)
0-4	55.73			55.4*		1.006		
5-9	59.43	58.78	59.29	60.2		.987	.976	.985
10-14	55.66	54.46	54.98	55.9		.996	.974	.991
15-19	51.37	48.99	49.50	51.5		.997	.951	.961
20-24	47.17	42.47	42.97	47.3		.997	.898	.908
25-29	43.11	37.58	38.07	43.4		.993	.866	.877
30-34	39.19	34.90	35.43	39.3		1.003	.888	.902
35-39	35.23	33.44	34.03	35.2		1.001	.95	.967
40-44	31.42	30.66	31.30	31.1		1.010	.986	1.006
45-49	27.39	27.83	28.51	27.0		1.014	1.031	1.056
50-54	23.55	23.63	24.33	23.0		1.024	1.027	1.058
55-59	19.96	20.33	21.10	19.1		1.045	1.064	1.105
60-64	16.10	17.75	18.61	15.5		1.039	1.145	1.201
65-69	13.08	14.61	15.58	12.1		1.081	1.207	1.288
70-74	9.56	12.33	13.51	9.2		1.039	1.340	1.468
75 +	6.15	6.23	6.58	6.9		.891	.903	.954

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CHAPTER IV

CAUSE OF DEATH ANALYSIS:

4.1 INTRODUCTION

In Chapter III above, life tables were constructed in which mortality was treated as a unitary force whose intensity was found to vary with age and sex. However, on the other hand, mortality can be viewed not as a single unitary force but as an agglomeration of semi-independent forces, each force being represented by death from a particular cause or group of causes.

This has been accomplished in this chapter in which life tables have been constructed by causes of death by using the single and multiple decrement approaches referred to as Method IV (a and b) in Chapter II. In order to construct life tables by causes of death by Method IV (a and b), the survival probabilities and the life table deaths obtained from the life tables constructed by Method II are used as intermediate results. Estimation of e(A) (A = 75), the expectation of life at the beginning of the open interval follows the Bennett - Horiuchi[1] (1982) Method.

Cause of death grouping in Kenya follows the international Statistical Classification. The Causes are classified into sixteen groups. In this study, however, cause of death analysis has been limited to seven main groups. The groups are:

i) Infective and parasitic
ii) Respiratory system diseases
iii) Circulatory system diseases
iv) Accidents
v) Nervous system diseases
vi) Digestive system diseases
and vii) Blood diseases.

For each group of causes, death probabilities have been computed at each age by the single and multiple decrement approaches. Second, life tables have been constructed if each cause of death were eliminated at a time by the multiple decrement approach. The mortality estimates presented in this Chapter should be taken as only indicative and not definite.

4.2 AGE AND SEX DIFFERENTIALS IN MORTALITY BY CAUSE OF DEATH.

Table 4.1 and 4.2 show the cause of death probabilities if mortality was only due to each of the groups of causes outlined above for males and females respectively under the single decrement approach. Similarly tables 4.3 and 4.4 show the cause of death probabilities under the multiple decrement approach for males and females respectively.

By examining tables 4.1 to 4.4 it is observed that the single decrement approach gives higher death probabilities than the multiple decrement approach for each cause of death and at each age for both males and females. A display of the cause of death age specific death probabilities in figure 4.1 and 4.2 for males shows that the pattern of the single decrement approach death probabilities is similar to the pattern of the multiple decrement death probabilities. Figure 4.3 and 4.4 show that for females, the patterns are also similar. From figures 4.1 to 4.4, we can therefore conclude that the chances of dying from a given cause of death at any age is invariant to the method of estimation (Single or multiple decrement approach) and that the only difference between the two sets of estimated death probabilities for a given sex is that the single decrement approach estimates are higher than the corresponding multiple decrement estimates.

We now look at each cause of death and findings for each group of causes of death analysis are summarized below:

(i) Infective and Parasitic diseases:

Both figure 4.1 and 4.2 show that for males, chances of dying from infective and parasitic diseases are highest at age 0 (i.e., at the 0-4 years age group). Then it declines rapidly at first and then steadily till it is lowest at age 15 when it starts increasing with age. It is the major cause of death below age 15 and at older ages (that is from age 55 onwards).

As for males, figure 4.3 and 4.4 shows that for females the probability of dying from infectious and parasitic diseases is highest at age 0 (i.e., at the 0-4 years of age). It then falls rapidly up to age 5 (i.e., in the 5-9 years age group) and then falls steadily and it is lowest at the 15-19 years age group. After which it starts rising with age. Unlike for males, it is further observed that for females, Infective and Parasitic diseases is the major cause of the death at all ages except, may be by error in the data, at age group 40 - 45 years.

From tables 4.5 and 4.6, which show the Sex Ratio death probabilities from the various causes of death, it is observed that Infective and Parasitic diseases as group of causes of death is more prevalent among females below ages 40 years than it is among males. From age 50 onwards, the risk is higher among males than it is among females.

(ii) Respiratory System diseases:

Respiratory system diseases affect both males and females more at younger ages (0 to 4 years) than at old ages. Under age 10 years, it is the second leading cause of death for both males and females. The chances of dying from respiratory system diseases have been found to be lowest at age 20 for males and at age 15 for females.

Table 4.5 and 4.6 shows that respiratory system diseases as a cause of death is more prevalent among females than it is among males at all ages below 25 years. Thereafter, survival chances are more unfavourable for males than for females. The sex ratios are highest at age group 55 - 59 years. It also should be noted that respiratory system diseases is the third major cause of deaths at older ages (i.e. from age 60 years onwards) for both males and females.

(iii) Circulatory System diseases

Circulatory system diseases affect both males and females more at older ages than at young ages. The mortality patterns follow the 'J' shape for both males and females. It is the major cause of death for males between ages 45 and 54 years. Thereafter it is the second major cause of death.

For females, it is the second major cause of death from age 30 onwards and it is even observed that at age group 35 to 40 years, it is the major cause of death. We would however like to note that this observation might be due to some error in age reporting.

Both table 4.5 and 4.6 show that the disease is more prevalent among females than in males at ages lower than 30 years. At age group 35 to 40 years table 4.6 shows that the sex ratio is unity. Meaning that at this age group, chances of dying from circulatory system diseases for males are equal to those for females. After age 40, the disease is seen to be more prevalent among males.

(iv) Accidents:

Unlike the three groups of causes of death analysed above, the mortality pattern from accidents for males is neither 'U' nor 'J' shaped. It is observed from figure 4.1 and 4.2 that while the intensity of accidents as a cause of death is least at younger ages, it is the leading cause of death between ages 15 and 45 years. The death probability starts rising rapidly from age 15 and reaches its maximum at group 40 to 45 years. Thereafter it starts declining slowly and then rising at age 70 years. Note that it is the third leading cause of death between age 45 and 60 years among males.

Accidents as a cause of death seems to affect women less. It should however be noted that between ages 15 and 30 years, it is the second leading cause of death among females.

Mortality Sex Ratios for accidents shows that although females under 15 years of age are more likely to die from accidents, the risk is more unfavourable for males from age 15 onwards. We also note that within this age range, accidents have the highest Sex ratio. Being as high as 4.94 at age group 40 to 44 years under the multiple decrement approach.

The prevalence of accidents as a cause of death for males above age 15 years coincides with the active years of life (i.e. 15 to 65 years of age).

(v) Nervous System diseases:

The shape of the death probabilities from nervous system diseases is 'J' for males while it is more 'U' shaped for females. Chances of dying from this group of diseases is lowest at age group 20 to 25 years for males and at age group 15 to 20 years for females. For both males and females nervous system diseases as a cause of death is the fifth leading cause of death at age group 0 to 4 years.

The mortality sex ratios show that below age 25 years, the cause is more prevalent among females than it is among males. From there onwards survival probabilities from nervous system diseases are less favourable for males than they are for females. Among the causes under consideration, we note that it is the second least prevalent cause of death for males, and it is the third least prevalent cause of death for females.

(vi) Digestive System diseases

The single decrement approach shows that for both males and females, the mortality pattern due to digestive system diseases is more 'J' shaped. That is the disease as a cause of death is more prevalent at old ages than at younger ages. Under the multiple decrement approach, the mortality pattern is more 'U' shaped for females while for males it is still 'J' shaped as was the case under the single decrement approach. Table 4.5 and 4.6 show that the Sex ratios for digestive system diseases are less than unity for ages under 30 years. For ages over 30 years, the sex ratios are greater than unity. That means that digestive system diseases as a cause of death are more prevalent among females at ages lower than 30 years. Afterwards the group as a cause of death is more prevalent among males than among females.

(vii) Blood diseases:

The multiple decrement approach shows that for both males and females, the disease is more prevalent at younger ages (i.e. 0 to 4 years age group) than at old ages. However, the single decrement approach shows that the disease affects both the old and the youth equally. Thus one thing is clear, the disease is more prevalent at the younger ages. In any case, the patterns nearly follow the 'U' shape.

The mortality sex ratio shows that the disease is more prevalent among females to males at ages lower than 55 years.

Among the causes considered in this study, it is the fourth leading cause of death at ages 0 to 4 years and the least cause of death from age 10 onwards. For females, it seems to exchange patterns with nervous system diseases.

Table 4.1: $_nQ_x \times 1000$ Values for Specific Causes (Single Decrement) Males.

Age Group	Infectives & Parasitic	Respiratory System Dis.	Circulatory System	Accidents	Nervous	Diges-tive	Blood
0-4	43.1	28.0	9.0	2.6	7.4	3.4	7.8
5-9	5.7	2.2	1.9	1.5	1.3	.6(=1.0)	.97 (1.0)
10-14	3.0	1.1	1.6	1.3	1.4	.48(.5)	.4
15-19	2.4	.96(1.0)	1.8	2.7	.99(1.0)	.88(1.0)	.68
20-24	2.7	.8(1.0)	1.6	6.5	.85=.9 (1.0)	1.2	.5
25-29	3.3	2.2	3.1	9.5	1.5	1.9	.61
30-34	5.2	2.6	3.7	10.8	1.6	2.6	1.2
35-39	7.4	3.5	5.5	11.9	.96 (1.0)	3.2	1.1
40-44	9.5	4.6	7.0	12.3	2.1	4.3	1.3
45-49	11.5	5.0	13.4	11.2	2.3	6.2	1.8
50-54	17.5	6.8	19.2	11.4	3.7	9.99 (10.0)	2.8
55-59	24.4	7.5	22.2	11.4	3.8	9.6	2.1
60-64	35.0	19.5	34.9	10.2	5.2	15.5	7.9
65-69	46.0	16.9	37.8	9.7	8.2	16.3	6.7
70-74	58.1	31.1	55.8	14.7	11.8	13.9	7.3
75 +							

Table 4.2: $_nQ_x \times 10^3$ *For Special Causes of Death for Females (Single Decrement)*

(Death Probabilities with A Specific Cause as the Only Cause of Death)

Age Group	Infective & Parasitic	Respiratory System Diseases	Circulatory System Diseases	Accidents	Nervous System Diseases	Digestive System Diseases	Blood Diseases
0-4	55.08	37.31	11.26	3.51	8.19	4.75	10.18
5-9	8.33	2.78	2.57	1.97	1.51	.76	1.33
10-14	3.24	1.38	2.27	1.38	1.49	.78	1.16
15-19	3.05	1.33	2.29	2.62	1.24	1.19	1.19
20-24	4.51	1.89	2.56	3.29	1.65	1.34	1.34
25-29	5.65	1.79	3.42	3.79	1.12	2.09	1.64
30-34	6.03	1.69	5.5	3.91	1.07	2.04	1.42
35-39	8.88	4.19	5.75	3.87	2.2	2.51	1.15
40-44	6.27	3.33	6.64	3.08	1.36	3.33	2.10
45-49	12.51	4.04	8.21	4.63	2.24	3.59	2.54
50-54	17.02	4.97	15.21	4.24	2.58	5.71	2.95
55-59	19.93	4.34	14.31	5.93	3.2	5.25	1.83
60-64	33.21	17.02	33.49	6.45	6.45	12.03	5.33
65-69	40.35	11.04	34.49	4.29	7.49	9.98	2.15
70-74	58.04	20.86	48.30	5.87	9.27	11.69	8.78
75 +							

Table 4.3: $_nQ_x \times 10^3$ Values for Particular Causes of Death (Multiple Decrement) Males

Age Group	Infective & Parasitic	Respiratory System Diseases	Circulatory System Diseases	Accidents	Nervous System	Digestive System Diseases	Blood Diseases
0-4	41.52	26.83	8.54	2.45	7	3.23	7.39
5-9	5.23	1.97	1.65	1.30	1.15	.53	.86
10-14	2.76	.96	1.38	1.11	1.2	.42	.36
15-19	2.18	.86	1.58	2.37	.86	.76	.6
20-24	2.43	.77	1.34	5.62	.73	1.06	.45
25-29	2.89	1.89	2.6	8.04	1.22	1.62	.51
30-34	4.45	2.19	3.06	8.99	1.35	2.14	.94
35-39	6.14	2.86	4.41	9.62	.76	2.53	.36
40-44	7.7	3.57	5.41	9.70	1.59	3.24	.96
45-49	8.87	3.68	9.86	8.44	1.64	4.5	1.31
50-54	12.73	4.72	13.39	8.07	2.48	6.79	1.38
55-59	16.5	4.8	14.36	7.4	2.33	5.99	1.29
60-64	21.46	11.16	20.39	5.9	2.86	8.68	4.31
65-69	24.7	8.35	19.22	4.82	3.86	7.83	3.13
70-74	26.33	12.73	23.95	6.04	4.57	5.52	2.8
75 +							

Table 4.4: *Death Probabilities ($_nQ_x \times 10^3$) With A Specific Cause as the Only Cause of Death for Females (Multiple Decrement)*

Age Group	Infective & Parasitic	Respiratory System Diseases	Circulatory System Diseases	Accidents	Nervous System Diseases	Digestive System Diseases	Blood Diseases
0-4	52.58	35.29	10.51	3.26	7.63	4.41	9.5
5-9	7.5	2.46	2.21	1.68	1.30	.64	1.14
10-14	2.88	1.20	1.92	1.16	1.26	.66	.98
15-19	2.68	1.14	1.92	2.17	1.03	.99	.99
20-24	3.90	1.59	2.10	2.69	1.35	1.10	1.10
25-29	4.8	1.47	2.76	3.03	.89	1.66	1.32
30-34	5.02	1.36	4.33	3.05	.83	1.58	1.11
35-39	7.20	3.26	4.41	2.94	1.66	1.89	.87
40-44	4.95	2.52	4.94	2.26	1.00	2.43	1.54
45-49	9.55	2.95	5.90	3.28	1.58	2.53	1.79
50-54	12.45	3.44	10.45	2.85	1.72	3.82	1.97
55-59	13.87	2.83	9.32	3.76	2.01	3.30	1.15
60-64	21.38	10.14	20.13	3.72	3.68	6.90	3.04
65-69	23.30	5.79	18.53	2.17	3.76	5.04	1.08
70-74	29.33	9.38	22.55	2.51	3.96	5.03	3.74
75 +							

Table 4.5: Sex Ratios of Age Specific Death Probabilities ($_nQ_x \times 10^3$) For Various Causes. (Single Decrement)

Age Group	Infective & Parasitic	Respiratory System Diseases	Circulatory System Diseases	Accidents	Nervous System Diseases	Digestive System Diseases	Blood Diseases
0-4	.782	.750	.799	.741	.904	.716	.766
5-9	.684	.791	.739	.761	.861	.789	.729
10-14	.926	.797	.705	.942	.940	.615	.345
15-19	.787	.722	.786	1.031	.798	.739	.571
20-24	.599	.423	.625	1.976	.515	.896	.373
25-29	.584	1.229	.906	2.507	1.339	.909	.372
30-34	.862	1.538	.673	2.762	1.495	1.275	.845
35-39	.833	.835	.957	3.075	.436	1.275	.957
40-44	1.515	1.381	1.054	3.994	1.544	1.291	.619
45-49	.919	1.238	1.632	2.419	1.027	1.727	.709
50-54	1.028	1.368	1.262	2.689	1.434	1.750	.949
55-59	1.224	1.728	1.551	1.922	1.188	1.829	1.148
60-64	1.054	1.146	1.042	1.581	.806	1.288	1.482
65-69	1.140	1.531	1.096	2.261	1.095	1.633	3.116
70-74	1.001	1.491	1.155	2.504	1.273	1.189	.831
75 +							

Table 4.6: Sex Ratios of Death Probabilities ($_5Q_x \times 10^3$) For Various Causes (Multiple Decrement)

Age Group	Infective & Parasitic	Respiratory System Diseases	Circulatory System Diseases	Accidents	Nervous System Diseases	Digestive System Diseases	Blood Diseases
0-4	.790	.760	.813	.752	.917	.732	.778
5-9	.697	.801	.747	.774	.885	.828	.754
10-14	.958	.800	.719	.957	.952	.636	.367
15-19	.813	.754	.823	1.092	.835	.768	.606
20-24	.623	.484	.638	2.089	.541	.964	.409
25-29	.602	1.286	.942	2.653	1.371	.976	.386
30-34	.886	1.610	.707	2.948	1.627	1.354	.847
35-39	.853	.877	1.000	3.272	.458	1.339	.989
40-44	1.556	1.417	1.095	4.292	1.59	1.333	.623
45-49	.929	1.247	1.671	2.573	1.038	1.779	.732
50-54	1.022	1.372	1.281	2.832	1.442	1.777	.954
55-59	1.190	1.696	1.541	1.968	1.159	1.815	1.122
60-64	1.004	1.106	1.013	1.586	.777	1.258	1.418
65-69	1.060	1.442	1.037	2.221	1.027	1.554	2.898
70-74	.898	1.357	1.062	2.406	1.154	1.097	.749
75 +							

Fig.4.1 DEATH PROBABILITIES (BY SINGLE DECREMENT) FOR VARIOUS CAUSES COMPARED, MALES: 1979

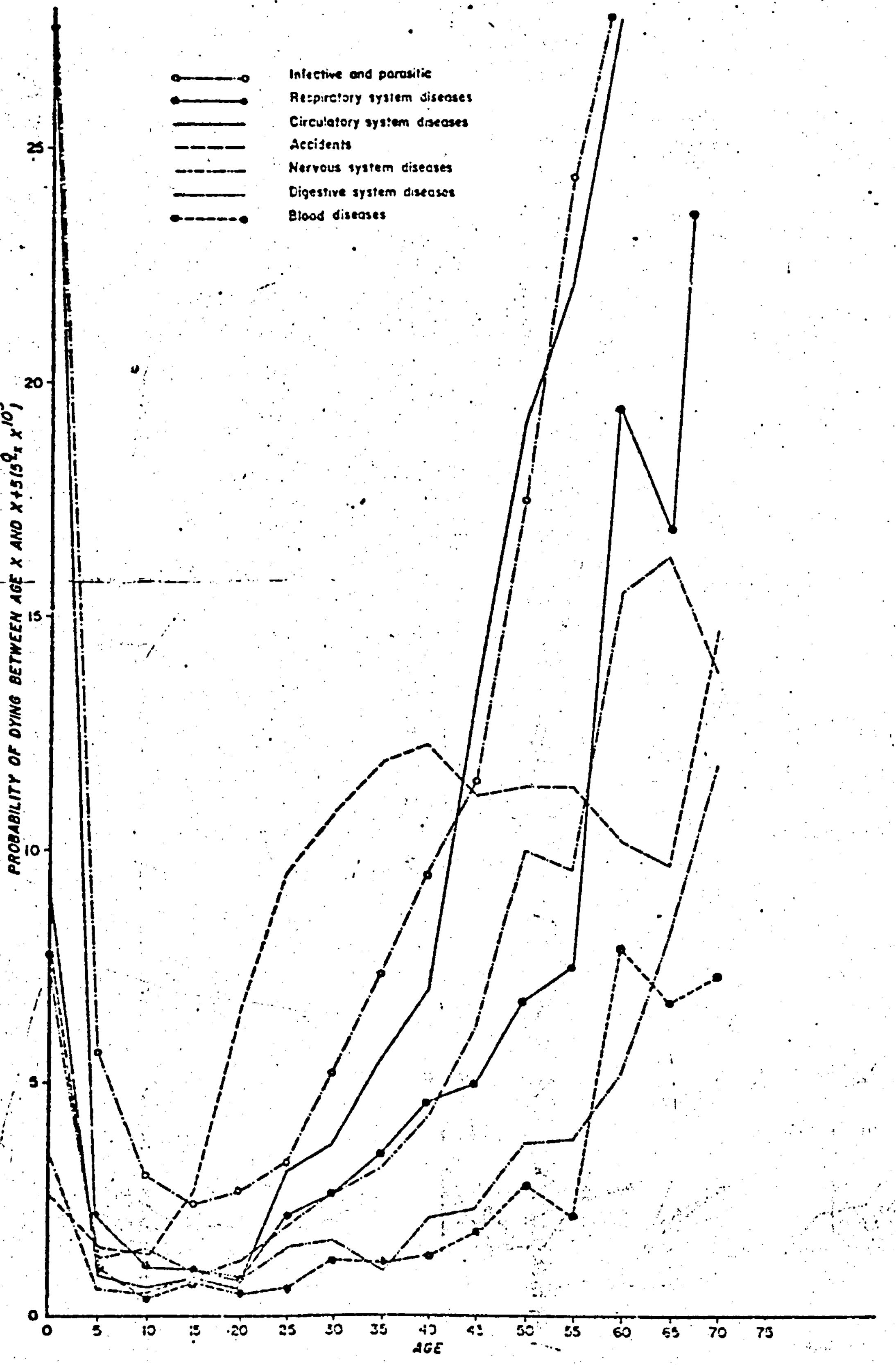


Fig.4.3 DEATH PROBABILITIES FOR VARIOUS CAUSES FOR MALES (MULTIPLE DECREMENT APPROACH)

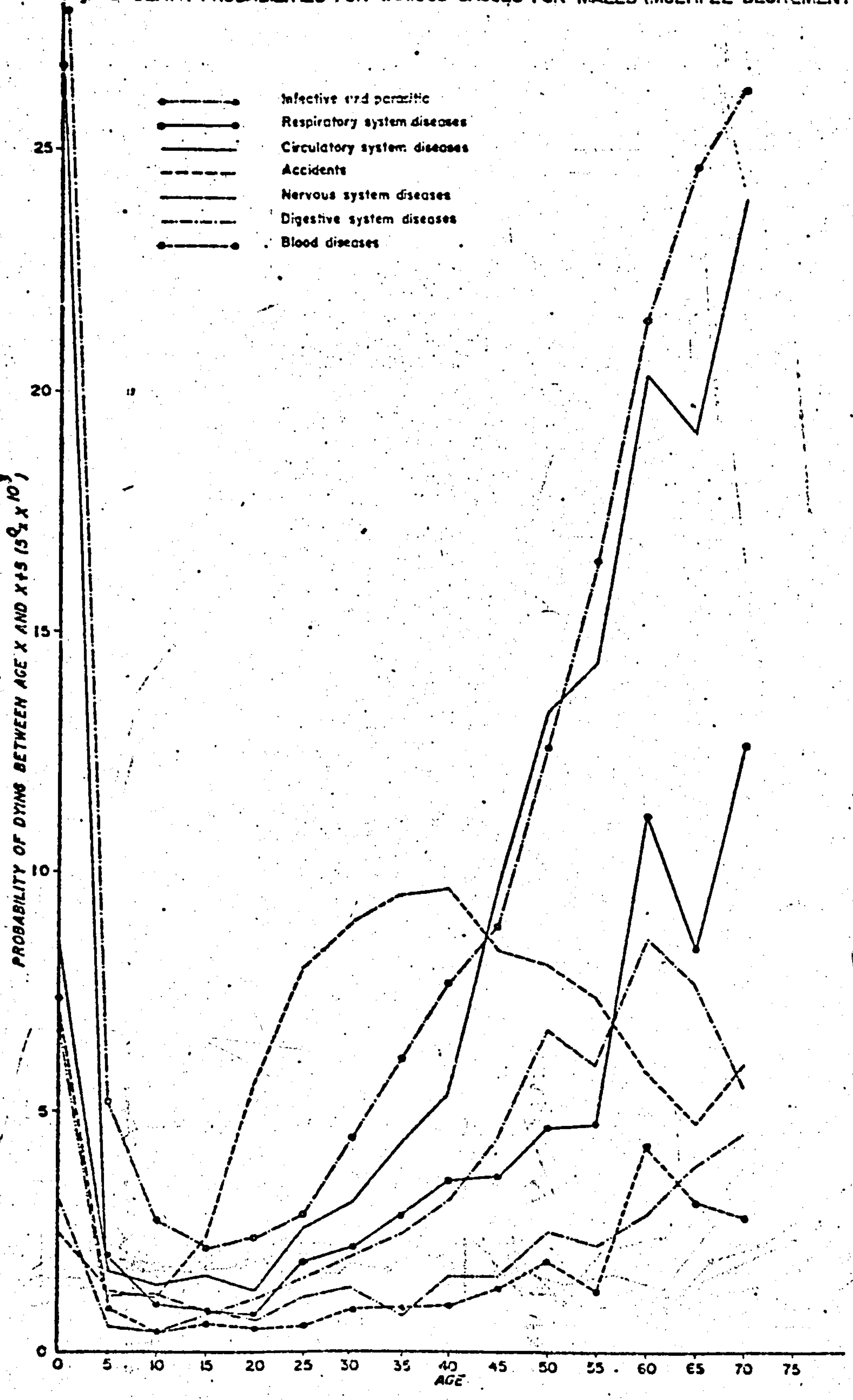


Fig.4.3 DEATH PROBABILITIES (BY SINGLE DECREMENT) FOR VARIOUS CAUSES COMPARED, FEMALES 1979

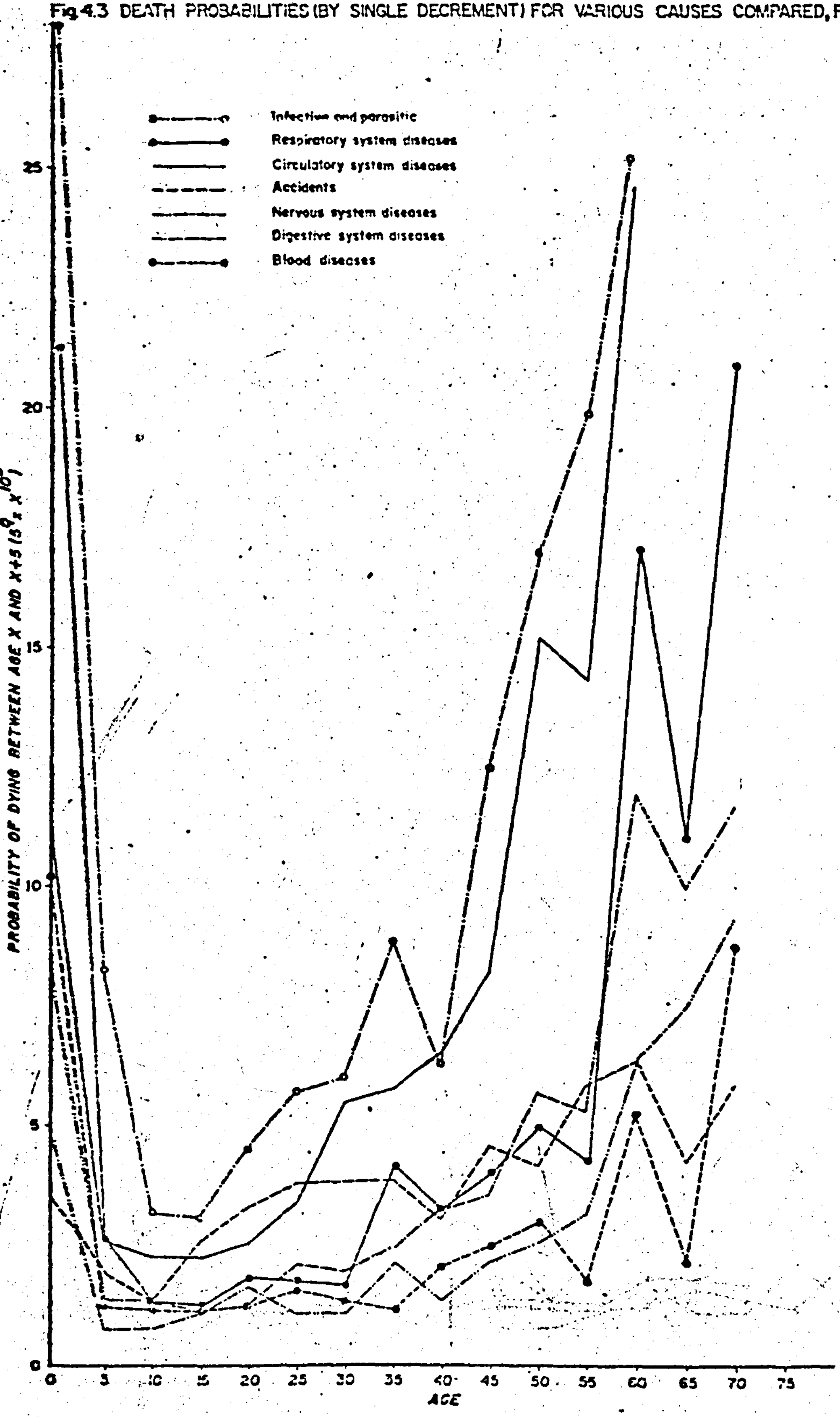
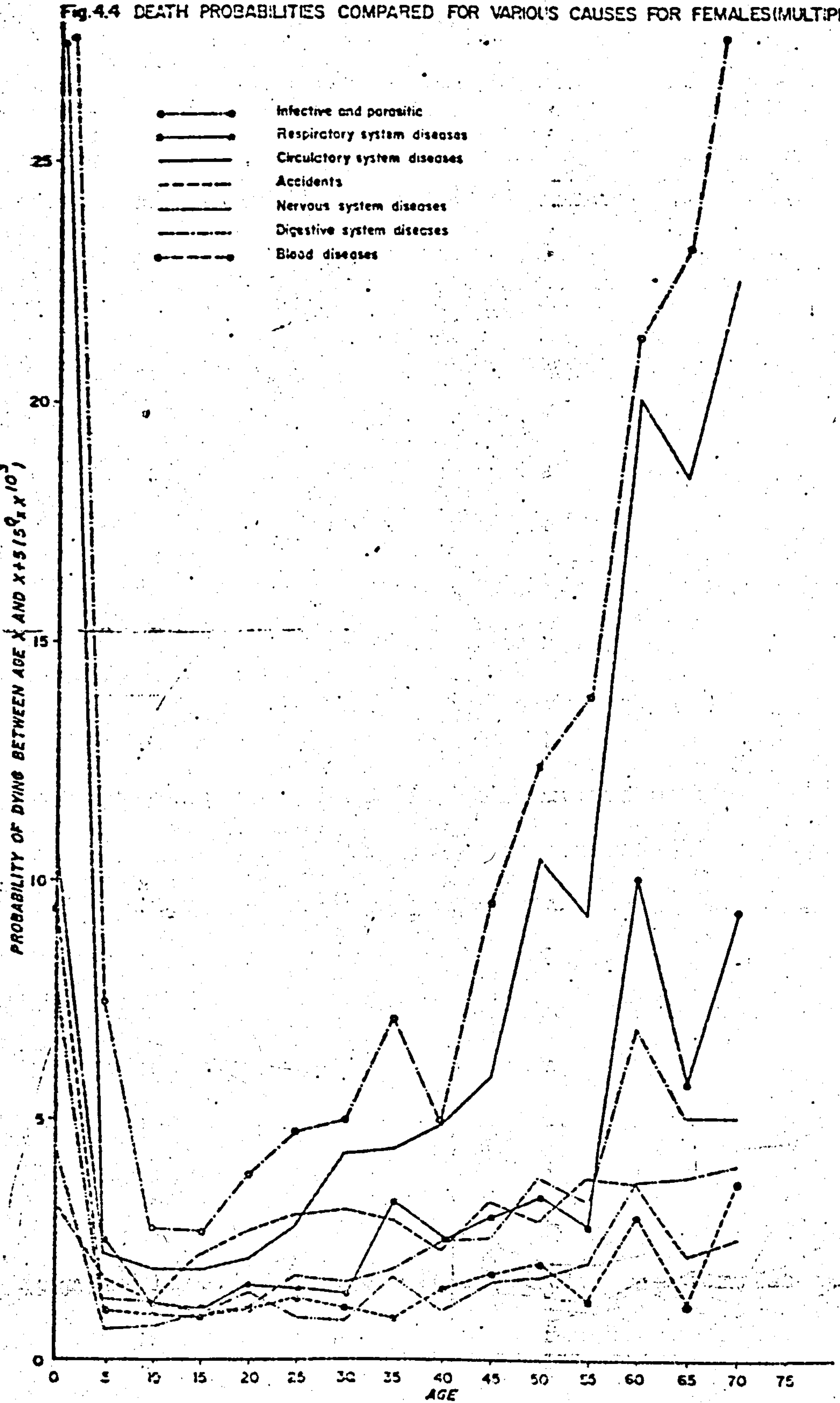


Fig.4.4 DEATH PROBABILITIES COMPARED FOR VARIOUS CAUSES FOR FEMALES(MULTIPLE DECREMENT)



4.3 HYPOTHETICAL GAIN IN LIFE EXPECTANCY BY CAUSE OF DEATH ELIMINATION

In Section 4.2 above, we have seen how the various causes of death affect human life throughout the life span. In this Section, we go further to determine what would be the structure of mortality in Kenya if some causes of death were eliminated from our society. For this, we shall restrict ourselves to the multiple decrement life table results since in reality no cause of death occurs completely in isolation from other causes as proposed in the single decrement approach. In reality, most deaths result from a chain of preceeding conditions.

Life tables by the multiple decrement approach when various causes of death are eliminated using the 1979 registered deaths are displayed in tables 4.7 to 4.20. Given in the last column in each table is the gain in life expectancy values. The gain in life expectancy values are given by $\bar{e}_x^{-i} - e_x$ where $\bar{e}_x^{-i}$ is the life expectancy at age x when cause i is eliminated from the population as a cause of death and e_x is the life expectancy at age x with all causes of death present. In this study, the e_x (x = 0, ... 75) values used in computing $\bar{e}_x^{-i} - e_x$ are obtained from table 3.3.2 and 3.3.4 for males and females respectively as obtained by Method II in Chapter III.

A commonly used mortality index which summarizes mortality experience of all ages but is independent of the age structure is the life expectancy at birth. But life expectancy at birth as determined by Method II whose results are used as intermediate values in the construction of life tables by cause of death in this Chapter is said to be unreliable. For this reason, we therefore use life expectancy at age 5 as a rough index of what would be the gain in life expectancy after elimination of the various causes of death.

For males, the gain in life expectancy at age 5 is highest (5.74 years) when infective and parasitic diseases are eliminated as a cause of death. Infective and Parasitic diseases are followed by Accidents (4.86 years), circulatory system diseases (4.36 years), digestive system diseases (2.53 years); nervous system diseases (1.93 years) and lastly blood diseases (1.65 years).

For females, gain in life expectancy at age 5 is highest (6.83) years if infective and parasitic diseases are eliminated. Followed by respiratory system diseases (5.10 years), circulatory system diseases (4.89 years), accidents (3.27 years), digestive system diseases (2.78 years), blood diseases (2.50 years) and lastly, nervous system diseases (2.35 years).

The gain in life expectancy at age 5 shows that the order in gain of life expectancy differs between males and females thus revealing the differential intensity of each cause of death among the sexes. Further the life expectancy at age 5 values shows that except for accidents and blood diseases, the gain in life expectancy is more among females than it is among males. In general, it can be concluded that infective and parasitic diseases claim many lifes in Kenya as evidenced from its death probabilities and the gain in life expectancy when it is eliminated as a cause of death.

4.4 DISCUSSION

In the construction of life tables by causes of death, we calculated the survival probability under cause i as the only cause of death, ${}_nP^i_x$ as equal to

$$\left[{}_nP_x\right]^{\frac{{}_nM^i_x}{{}_nM_x}}$$

where ${}_nP_x$ is the survival probability when all causes of death are present in the population, ${}_nM^i_x$ is the age specific mortality rate when all causes of death are eliminated except cause i and ${}_nM_x$ is the age specific mortality rate when all causes of death act on the population. The ${}_nP_x$ values used in the construction of life tables by causes of death are obtained from tables 3.3.2 and 3.3.4 in Chapter III above. We note that in the estimation of

$${}_nP_x^i = \left[{}_nP_x\right]^{\frac{{}_nM_x^i}{{}_nM_x}}$$

We need not correct ${}_nM_x^i$ and ${}_nM_x$ values for underregistration if the completeness of death registration does not vary with age and cause of death.

If we were however to follow Preston and Coale[2] (1982) suggestion, we could have first adjusted ${}_nP_x$ for underregistration. They argue that if ${}_nP_x$ is the survival probability calculated from incomplete death registration data and C is the completeness of death registration in the population, then

$${}_nP_x^* = {}_nP_x^{1/c}$$

where ${}_nP_x^*$ is the adjusted survival probability i.e.; survival probability if the completeness of death registration was 100 per cent.

In this study however, under the single decrement approach, we have simply used the equation

$$ {}_nP^i_x = \left[{}_nP_x\right]^{\frac{{}_nM^i_x}{{}_nM_x}} $$

to give a rough estimate of the survival probability if death was only due to cause i.

Under the multiple decrement approach we first start by calculating ${}_nd^i_x$ (life table number of deaths due to cause i). We have

$$ {}_nd^i_x = \frac{{}_nD^i_x}{{}_nD_x} \cdot {}_nd_x $$

where ${}_nd_x$ is the life table number of deaths when all causes of death are present, ${}_nD_x$ is observed number of deaths due to all causes and ${}_nD^i_x$ is the number of deaths due to cause i. We also note that in the estimation of ${}_nd^i_x$ hence ${}_np^i_x$ we need not know the completeness of death registration since correction of death registration will affect both ${}_nD^i_x$ and ${}_nD_x$ equally and will cancel each other out.

Hence if there will be any difference between the ${}_nP^i_x$ estimates as obtained by the Preston and Coale (1982) Method; single decrement approach and the multiple decrement approach, the difference will not affect the age mortality patterns.

Now for all causes of death except for accidents, it has been found that the general age patterns of mortality nearly conforms to the usual 'U' or 'J' shapes. Which means that the chances of survival under any given cause of death are always low at the beginning and/or at the end of the life span, highest at the eve of puberty and high and gradually descending during the long period of adulthood.

Contrary to the usual phenomenon that male infant and childhood mortality is high than female infant and childhood mortality, the study has found that the risk of dying from any given cause of death is higher for females than for males at the younger years of life. This holds even when all causes of death are considered in the construction of life tables as noted in Chapter III Section 3.3 where the e_o value for females is lower than the e_o value for males as given in table 3.3.2 and 3.3.4. This finding calls for an intensive investigation into the possible factors responsible for this departure from normality.

The age and sex differentials in mortality as observed can be attributed to the causative factors affecting mortality throughout the life span. The causative factors belong to two groups, though by no means sharply demarcated. One group can be referred to as environmental;

exogeneous or socio-economic factors, and the other as biological, endogeneous or developmental factors. In this study, we simply gave the two groups as environmental and demographic factors as stated in the theoretical statement.

Differentials in mortality by sex can be explained by a continuous interplay between these two groups of factors. In other words, a lowered mortality in one sex may be due to a 'genetic superiority' over the other sex, or result from less exposure to hazardous environmental factors. "The female sex . . . does appear to be genetically superior, or in other words, there is an innate frailty of the male".[3]

In the theoretical statement we formulated the following preliminary model,

$$M = D + E + O$$

where (E) is the environmental component of mortality (M), (D) is the demographic component and (O) is the obstetrical component considered separately at the early years of life.

One may assume that under usual conditions the (E) and (O) components are the same for both sexes. On the other hand, as explained above, the demographic component (biological) for males $D_{(m)}$ is greater than $D_{(f)}$, that for females. Accordingly, the mortality sex ratio (MSR) can be represented as follows:

$$MSR = \frac{M_{(m)}}{M_{(f)}} = \frac{D_{(m)} + E+O}{D_{(f)} + E+O}$$

Based on the fundamental assumptions, $M_{(m)}$ will be greater than $M_{(f)}$, and MSR will be greater than unity. Furthermore, it may be expected that whenever the environmental (E) and/or the obstetrical components are small, the difference in the demographic (biological) (D) component will be more prevalent, hence the differentials by sex increase or vice versa.

We also note that since the obstetrical (O) component was introduced to carter for mortality in earlier years, its importance in the causation of mortality is expected to be more manifest earliest in life and dwindles afterwards. Thus in latter years of life mortality is mainly affected by the environmental and demographic factors.

In our cause of death analysis, the sex differentials observed are in line with the proposed model. For instance, infective and parasitic diseases and respiratory system diseases are evidently environmental in origin and affect both sexes. Accordingly at ages below 40 for Infective and Parasitic diseases and below age 30 for respiratory system diseases where they assume great importance, they overshadow any demographic (biological) difference between the two sexes, and the MSR is less than unity. In older ages, on the other hand men are more exposed than women to these factors, hence the increase in the MSR (MSR becomes greater than unity).

The less favourable male mortality from the group of accidents is definitely due to the greater exposure of man. We realise that in Kenya as in many other developing countries, usually man is the breadwinner and since accident - prevention measures are not widely and effectively implemented, it is natural to have a high MSR. The MSR is more so expected to be higher in the active working age. The sex mortality differential has been found to be high from age 15 onwards. Being highest at the 40 to 45 years age group.

In line with the proposed model, we now see how even the sex differentials in number of years gained by eliminating some causes of death can be explained.

Table 4.7 Life Table Eliminating Infective and Parasitic Diseases as A Cause of Death For the Total Male Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancies

Age Group	${}_n\bar{P}^i_x$	${}_n\bar{Q}^i_x$	${}_n\bar{d}^i_x$	$\bar{\ell}^i_x$	${}_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.93044	.06956	6 956	100 000	482 610	6 483 852	64.84	7.88
5-9	.99096	.00904	841	93 044	463 118	6 001 242	64.50	5.74
10-14	.99325	.00675	622	92 203	459 460	5 538 124	60.06	5.44
15-19	.99089	.00911	834	91 581	455 820	5 078 664	55.46	5.3
20-24	.98771	.01229	1 124	90 747	450 925	4 622 844	50.94	5.2
25-29	.97996	.02004	1 796	89 623	443 625	4 171 919	46.55	5.12
30-34	.97668	.02332	2 048	87 827	434 015	3 728 294	42.45	5.04
35-39	.97290	.02710	2 325	85 779	423 083	3 294 279	38.40	4.91
40-44	.96629	.03371	2 813	83 454	410 238	2 871 196	34.40	4.74
45-49	.95936	.04064	3 277	80 641	395 013	2 460 958	30.52	4.55
50-54	.94214	.05786	4 476	77 364	375 630	2 065 945	26.70	4.34
55-59	.94227	.05773	4 208	72 888	353 920	1 690 315	23.19	4.06
60-64	.90930	.09070	6 229	68 680	327 828	1 336 395	19.46	3.7
65-69	.91091	.08909	5 564	62 451	298 345	1 008.567	16.15	3.21
70-74	.88518	.11482	6 532	56 887	268 105	710 222	12.48	2.62
75 +				50 355	442 117	442 117	8.78	1.98

${}_{30}\bar{d}^i_{10}/{}_{20}\bar{d}^i_{40} = .592$ Corresponding e(75) ≈ 8.78

Table 4.8 Life Table Eliminating Respiratory System Diseases as A Cause of Death For the For The Total Male Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age

Age Group	${}_n\bar{P}_x^i$	${}_n\bar{Q}_x^i$	${}_n\bar{d}_x^i$	$\bar{\ell}_x^i$	${}_n\bar{L}_x^i$	$\bar{T}_x^i$	$\bar{e}_x^i$	$\bar{e}_x^i - e_x$
0-4	.91575	.08425	8 425	100 000	478 938	6 151 768	61.52	4.56
5-9	.98744	.01256	1 150	91 575	455 000	5 672 830	61.95	3.19
10-14	.99124	.00876	792	90 425	450 145	5 217 830	57.70	3.08
15-19	.98931	.01069	958	89 633	445 770	4 767 685	53.19	3.03
20-24	.98557	.01443	1 280	88 675	440 175	4 321 915	48.74	3.00
25-29	.97841	.02159	1 887	87 395	432 258	3 881 740	44.42	2.99
30-34	.97362	.02638	2 256	85 508	421 900	3 449 482	40.34	2.93
35-39	.96846	.03154	2 626	83 252	409 695	3 027 582	36.37	2.88
40-44	.96045	.03955	3 189	80 626	395 158	2 617 887	32.47	2.81
45-49	.95163	.04837	3 746	77 437	377 820	2 222 729	28.70	2.73
50-54	.92952	.07048	5 194	73 691	355 470	1 844 909	25.04	2.68
55-59	.92338	.07662	5 248	68 497	329 365	1 489 439	21.74	2.61
60-64	.88795	.11205	7 087	63 249	298 528	1 160 074	18.34	2.58
65-69	.87646	.12354	6 938	56 162	263 465	861 546	15.34	2.4
70-74	.84577	.15423	7 592	49 224	227 140	598 081	12.15	2.29
75 +				41 632	370 941	370 941	8.91	2.11

${}_{30}\bar{d}_{10}^i / {}_{20}\bar{d}_{40}^i = .564$ Corresponding e(75) = 8.91

Table 4.9 Life Table Eliminating Circulatory System Diseases As A Cause of Death for the Total Male Population (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age

Age Group	${}_n\bar{p}^i_x$	${}_n\bar{Q}^i_x$	${}_n\bar{d}^i_x$	$\bar{\ell}^i_x$	${}_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.89746	.10254	10 254	100 000	474 365	6 139 211	61.39	4.43
5-9	.98687	.01313	1 178	89 746	445 785	5 664 846	63.12	4.36
10-14	.99155	.00845	748	88 568	440 970	5 219 061	58.93	4.31
15-19	.98992	.01008	885	87 820	436 888	4 778 091	54.41	4.25
20-24	.98593	.01407	1 223	86 935	431 618	4 341 203	49.94	4.2
25-29	.97884	.02116	1 814	85 712	424 025	3 909 585	45.61	4.18
30-34	.97418	.02583	2 167	83 898	414 073	3 485 560	41.55	4.14
35-39	.96978	.03022	2 470	81 731	402 480	3 071 487	37.58	4.09
40-44	.96210	.03790	3 004	79 261	388 795	2 669 007	33.67	4.01
45-49	.95880	.04120	3 142	76 257	373 430	2 280 212	29.90	3.93
50-54	.94040	.05960	4 358	73 115	354 680	1 906 782	26.08	3.72
55-59	.93684	.06316	4 343	68 757	332 928	1 552 102	22.57	3.44
60-64	.90316	.09684	6 238	64 414	306 475	1 219 174	18.93	3.17
65-69	.89755	.10245	5 960	58 176	275 980	912 699	15.69	2.75
70-74	.87316	.12684	6 623	52 216	244 523	636 719	12.19	2.33
75 +				45 593	392 196	392 196	8.64	1.84

${}_{30}\bar{d}^i_{10}/{}_{20}\bar{d}^i_{40} = .627$

Corresponding e(75) ≈ 8.64

Table 4.10 Life Table Eliminating Accidents As A Cause of Death For The Total Male Population in Kenya (Multiple Decrement) And The Corresponding Gain In Life Expectancy At Each Age

Age Group	$_n\bar{p}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.89137	.10863	10 863	100 000	472 843	6 143 681	61.44	4.48
5-9	.98640	.01360	1 212	89 137	442 655	5 670 838	63.62	4.86
10.14	.99120	.00880	774	87 925	437 690	5 228 183	59.46	4.84
15-19	.99076	.00924	805	87 151	433 743	4 790 493	54.97	4.81
20-24	.99077	.00923	797	86 346	429 738	4 356 750	50.46	4.72
25-29	.98508	.01492	1 276	85 549	424 555	3 927 012	45.90	4.47
30-34	.98116	.01884	1 588	84 273	417 395	3 502 457	41.56	4.15
35-39	.97620	.02380	1 968	82 685	408 505	3 085 062	37.31	3.82
40-44	.96779	.03221	2 600	80 717	397 085	2 676 557	33.16	3.50
45-49	.95781	.04219	3 296	78 117	382 345	2 279 472	29.18	3.21
50-54	.93474	.06526	4 883	74 821	361 898	1 897 127	25.36	3.00
55-59	.92835	.07165	5 011	69 938	337 163	1 535 229	21.95	2.82
60-64	.88307	.11693	7 592	64 927	305 655	1 198 066	18.45	2.69
65-69	.87313	.12687	7 274	57 335	268 490	892 411	15.56	2.62
70-74	.83584	.16416	8 218	50 061	229 760	623 921	12.46	2.60
75 +				41 843	394 161	394 161	9.42	2.62

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .456 Corresponding e(75) ≈ .942

Table 4.11 Life Table Eliminating Nervous System Diseases As A Cause of Death For The Total Male Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.89592	.10408	10 408	100 000	473 980	5 911 503	59.12	2.16
5-9	.98629	.01371	1 228	89 592	444 890	5 437 523	60.69	1.93
10-14	.99133	.00867	766	88 364	439 905	4 992 633	56.50	1.88
15-19	.98909	.01091	956	87 598	435 600	4 552 728	51.97	1.81
20-24	.98519	.01481	1 283	86 642	430 003	4 117 128	47.52	1.78
25-29	.97717	.02283	1 949	85 359	421 923	3 687 125	43.20	1.77
30-34	.97201	.02799	2 335	83 410	411 213	3 265 202	39.15	1.74
35-39	.96513	.03487	2 827	81 075	398 308	2 853 989	35.20	1.71
40-44	.95687	.04313	3 375	78 248	382 803	2 455 681	31.38	1.72
45-49	.94740	.05260	3 938	74 873	364 520	2 072 878	27.69	1.72
50-54	.92386	.07614	5 401	70 935	341 173	1 708 358	24.08	1.72
55-59	.91644	.08356	5 476	65 534	313 980	1 367 185	20.86	1.73
60-64	.86908	.13092	7 863	60 058	280 633	1 053 205	17.54	1.78
65-69	.85932	.14068	7 343	52 195	242 618	772 572	14.80	1.86
70-74	.81430	.18570	8 329	44 852	203 438	529 954	11.82	1.96
75 +				36 523	326 516	326 516	8.94	2.14

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .556 Corresponding e(75) = 8.94

Table 4.12 Life Table Eliminating Digestive System Diseases As A Cause of Death For The Total Male Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{l}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.89215	.10785	10 785	100 000	473 038	5 941 101	59.41	2.45
5-9	.98555	.01445	1 289	89 215	442 853	5 468 063	61.29	2.53
10-14	.99041	.00959	843	87 926	437 523	5 025 210	57.15	2.53
15-19	.98892	.01108	965	87 083	433 003	4 587 687	52.68	2.52
20-24	.98549	.01451	1 250	86 118	427 465	4 154 684	48.24	2.50
25-29	.97751	.02249	1 909	84 868	419 568	3 727 219	43.92	2.49
30-34	.97281	.02719	2 256	82 959	409 155	3 307 651	38.87	1.46
35-39	.96715	.03285	2 651	80 703	396 888	2 898 496	35.92	2.43
40-44	.95885	.04115	3 212	78 052	382 230	2 501 608	32.05	2.39
45-49	.95115	.04885	3 656	74 840	365 060	2 119 378	28.32	2.35
50-54	.93005	.06995	4 979	71 184	343 473	1 754 318	24.64	2.28
55-59	.92265	.07735	5 121	66 205	318 223	1 410 845	21.31	2.18
60-64	.88044	.11956	7 303	61 084	287 163	1 092 622	17.89	2.13
65-69	.87044	.12956	6 968	53 781	251 485	805 459	14.98	2.04
70-74	.82381	.17619	8 248	46 813	213 445	553 974	11.83	1.97
75 +				38 565	340 529	340 529	8.83	2.03

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40} = .582$ | Corresponding e(75) = 8.83

Table 4.13 Life Table Eliminating Blood Diseases As A Cause of Death For The Total Male Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age.

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_5\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.89631	.10369	10 369	100 000	474 078	5 888 603	58.89	1.93
5-9	.98598	.01402	1 257	89 631	445 013	5 414 525	60.41	1.65
10-14	.99039	.00961	849	88 374	439 748	4 969 512	56.23	1.61
15-19	.98878	.01122	982	87 525	435 170	4 529 764	51.75	1.59
20-24	.98486	.01514	1 310	86 543	429 440	4 094 594	47.31	1.57
25-29	.97631	.02369	2 019	85 233	421 118	3 665 154	43.00	1.57
30-34	.97146	.02854	2 375	83 214	410 133	3 244 036	38.98	1.57
35-39	.96515	.03485	2 817	80 839	397 153	2 833 903	35.06	1.57
40-44	.95595	.04405	3 437	78 022	381 518	2 436 750	31.23	1.57
45-49	.94677	.05323	3 970	74 585	363 000	2 055 232	27.56	1.59
50-54	.92268	.07732	5 460	70 615	339 425	1 692 232	23.96	1.60
55-59	.91440	.08560	5 577	65 155	311 833	1 352 807	20.76	1.63
60-64	.87044	.12956	7 719	59 578	278 593	1 040 974	17.47	1.71
65-69	.85705	.14295	7 413	51 859	240 763	762 381	14.70	1.76
70-74	.80876	.19124	8 500	44 446	200 980	521 618	11.74	1.88
75 +				35 946	320 638	320 638	8.92	2.12

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .561

Corresponding e(75) = 8.92

Table 4.14 Life Table Eliminating Infective and Parasitic Diseases As A Cause of Death for The Total Female Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age.

Age Group	${}_n\bar{P}^i_x$	${}_n\bar{Q}^i_x$	${}_n\bar{d}^i_x$	$\bar{\ell}^i_x$	${}_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.9121	.0879	8 790	100 000	478 025	6 521 265	65.21	9.48
5-9	.98797	.01203	1 097	91 210	453 308	6 043 240	66.26	6.83
10-14	.99065	.00935	843	90 113	448 458	5 589 932	62.03	6.37
15-19	.98785	.01215	1 085	89 270	443 638	5 141 474	57.59	6.22
20-24	.98504	.01496	1 319	88 185	437 628	4 697 836	53.27	6.10
25-29	.98129	.01871	1 625	86 866	430 268	4 260 208	49.04	5.93
30-34	.98010	.0199	1 696	85 241	421 965	3 829 940	44.93	5.74
35-39	.97635	.02365	1 976	83 545	412 785	3 407 975	40.79	5.56
40-44	.97629	.02371	1 934	81 569	403 010	2 995 190	36.72	5.30
45-49	.97137	.02863	2 280	79 635	392 475	2 592 180	32.55	5.16
50-54	.95985	.04015	3 106	77 355	379 010	2 199 705	28.44	4.89
55-59	.96424	.03576	2 655	74 249	364 608	1 820 695	24.52	4.56
60-64	.92085	.07915	5 667	71 594	343 803	1 456 087	20.34	4.24
65-69	.93314	.06686	4 408	65 927	318 615	1 112 284	16.87	3.79
70-74	.90445	.09555	5 878	61 519	292 900	793 669	12.90	3.34
75 +				55 641	500 769	500 769	9.00	2.85

${}_{30}\bar{d}^i_{10}/{}_{20}\bar{d}^i_{40} = .857$ Corresponding e(75) = 9.00

Table 4.15 Life Table Eliminating Respiratory System Diseases As A Cause of Death for The Total Female Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.89736	.10264	10 264	100 000	474 340	6 264 576	62.65	6.92
5-9	.98315	.01685	1 512	89 736	444 900	5 790 236	64.53	5.10
10-14	.98904	.01096	967	88 224	438 703	5 345 336	60.59	4.93
15-19	.98622	.01378	1 202	87 257	433 280	4 906 633	56.23	4.86
20-24	.98186	.01814	1 561	86 055	426 373	4 473 353	51.98	4.81
25-29	.97896	.02104	1 778	84 494	418 025	4 046 980	47.90	4.79
30-34	.97784	.02216	1 833	82 716	408 998	3 628 955	43.87	4.68
35-39	.97268	.02732	2 210	80 883	398 890	3 219 957	39.81	4.58
40-44	.97654	.02346	1 846	78 673	388 750	2 821 067	35.86	4.44
45-49	.96642	.03358	2 580	76 827	377 685	2 432 317	31.66	4.27
50-54	.95295	.04705	3 493	74 247	362 503	2 054 632	27.67	4.12
55-59	.95573	.04427	3 132	70 754	345 940	1 692 129	23.92	3.96
60-64	.91550	.08450	5 714	67 622	323 825	1 346 189	19.91	3.81
65-69	.91865	.08135	5 036	61 908	296 950	1 022 364	16.51	3.43
70-74	.89487	.10513	5 979	56 872	269 413	725 414	12.76	3.2
75 +				50 893	456 001	456 001	8.96	2.81

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .864 Corresponding e(75) = 8.96

Table 4.16 Life Table Eliminating Circulatory System Diseases As A Cause of Death For the Total Female Population in Kenya (Multiple Decrement) and The Corresponding Gain in Life Expectancy at Each Age.

Age Group	${}_n\bar{P}_x^i$	${}_n\bar{Q}_x^i$	${}_n\bar{d}_x^i$	$\bar{\ell}_x^i$	${}_n\bar{L}_x^i$	$\bar{T}_x^i$	$\bar{e}_x^i$	$\bar{e}_x^i - e_x$
0-4	.87003	.12997	12 997	100 000	467 508	6 063 330	60.63	4.90
5-9	.98174	.01826	1 589	87 003	431 043	5 595 822	64.32	4.89
10-14	.98918	.01082	924	85 414	424 760	5 164 779	60.47	4.81
15-19	.98642	.01358	1 147	84 490	419 583	4 740 019	56.10	4.73
20-24	.98228	.01772	1 477	83 343	413 023	4 320 436	51.84	4.67
25-29	.97800	.02200	1 801	81 866	404 828	3 907 413	47.73	4.62
30-34	.97831	.02169	1 737	80 065	395 983	3 502 585	43.75	4.56
35-39	.97179	.02821	2 210	78 328	386 115	3 106 602	39.66	4.43
40-44	.97493	.02507	1 908	76 118	375 820	2 720 487	35.74	4.32
45-49	.96523	.03477	2 580	74 210	364 600	2 344 667	31.60	4.21
50-54	.95495	.04505	3 227	71 630	350 083	1 980 067	27.64	4.09
55-59	.95605	.04395	3 006	68 403	334 500	1 629 984	23.83	3.87
60-64	.91357	.08643	5 652	65 397	312 855	1 295 484	19.81	3.71
65-69	.92127	.07873	4 704	59 745	286 965	982 629	16.45	3.37
70-74	.88550	.11450	6 302	55 041	259 450	695 664	12.64	3.08
75 +				48 739	436 214	436 214	8.95	2.80

${}_{30}\bar{d}^i_{10}/{}_{20}\bar{d}^i_{40} = .867$ Corresponding e(75) = 8.95

Table 4.17 Life Table Eliminating Accidents As A Cause of Death for The Total Female Population in Kenya (Multiple Decrement) and The Corresponding Gain in *Life Expectancy at Each Age*

Age Group	$_n\bar{p}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.86278	.13722	13 722	100 000	465 695	5 875 330	58.75	3.02
5-9	.98098	.01902	1 641	86 278	427 288	5 409 635	62.70	3.27
10-14	.98820	.01180	999	84 637	420 688	4 982 347	58.87	3.21
15-19	.98661	.01339	1 120	83 638	415 390	4 561 659	54.54	3.17
20-24	.98283	.01717	1 417	82 518	409 048	4 146 269	50.25	3.08
25-29	.97815	.02185	1 772	81 101	401 075	3 737 221	46.08	2.97
30-34	.97655	.02345	1 860	79 329	391 995	3 336 146	42.05	2.86
35-39	.96965	.03035	2 351	77 469	381 468	2 944 151	38.00	2.77
40-44	.97118	.02882	2 165	75 118	370 178	2 562 683	34.12	2.70
45-49	.96122	.03878	2 829	72 953	357 693	2 192 505	30.05	2.66
50-54	.94364	.05636	3 952	70 124	340 740	1 834 812	26.17	2.62
55-59	.94671	.05329	3 526	66 172	322 045	1 494 072	22.58	2.62
60-64	.88529	.11471	7 186	62 646	295 265	1 172 027	18.71	2.61
65-69	.88815	.11185	6 203	55 460	261 793	876 762	15.81	2.73
70-74	.83556	.16444	8 100	49 257	226 035	614 969	12.48	2.92
75 +				41 157	388 934	388 934	9.45	3.3

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .763 Corresponding e(75) = 9.45

Table 4.18 Life Table Eliminating Nervous System Diseases As the Only Cause of Death For the Total Female Population in Kenya (Multiple Decrement) and the Corresponding Gain in Life Expectancy at Each Age.

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.86715	.13285	13 285	100 000	466 788	5 824 052	58.24	2.51
5-9	.97755	.02245	1 947	86 715	428 708	5 357 264	61.78	2.35
10-14	.98833	.01167	989	84 768	421 368	4 928 556	58.14	2.48
15-19	.98527	.01473	1 234	83 779	415 810	4 507 188	53.80	2.43
20-24	.98117	.01883	1 551	82 545	408 848	4 091 378	49.57	2.40
25-29	.97550	.02450	1 984	80 994	400 010	3 682 530	45.47	2.36
30-34	.97369	.02631	2 079	79 010	389 853	3 282 520	41.55	2.36
35-39	.96782	.03218	2 476	76 931	378 465	2 892 667	37.60	2.37
40-44	.96926	.03074	2 289	74 455	366 553	2 514 202	33.77	2.35
45-49	.95850	.04150	2 995	72 166	353 343	2 147 649	29.76	2.37
50-54	.94129	.05871	4 061	69 171	335 703	1 794 306	25.94	2.39
55-59	.94327	.05673	3 694	65 110	316 315	1 458 603	22.40	2.44
60-64	.88299	.11701	7 186	61 416	289 115	1 142 288	18.60	2.50
65-69	.88851	.11149	6 046	54 230	256 035	853 173	15.73	2.65
70-74	.83484	.16516	7 958	48 184	221 025	597 138	12.39	2.83
75 +				40 226	376 113	376 113	9.35	3.20

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .791   Corresponding e(75) ≈ 9.35

Table 4.19 Life Table Eliminating Digestive System Diseases As A Cause of Death for The Total Female Population in Kenya (Multiple Decrement) and the Corresponding Gain in Life Expectancy at Each Age.

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.86393	.13607	13 607	100 000	465 983	5 840 311	58.40	2.67
5-9	.97981	.02019	1 744	86 393	427 605	5 374 328	62.21	2.78
10-14	.98762	.01238	1 048	84 649	420 625	4 946 723	58.44	2.78
15-19	.98519	.01481	1 238	83 601	414 910	4 526 098	54.14	2.77
20-24	.98088	.01912	1 575	82 363	407 878	4 111 188	49.92	2.75
25-29	.97640	.02360	1 907	80 788	399 173	3 703 310	45.84	2.73
30-34	.97459	.02541	2 004	78 881	389 395	3 304 137	41.89	2.70
35-39	.96809	.03191	2 453	76 877	378 253	2 914 742	37.91	2.68
40-44	.97115	.02885	2 147	74 424	366 753	2 536 489	34.08	2.66
45-49	.95986	.04014	2 901	72 277	354 133	2 169 736	30.02	2.63
50-54	.94443	.05557	3 855	69 376	337 243	1 815 603	26.17	2.62
55-59	.94554	.05446	3 568	65 521	318 685	1 478 360	22.56	2.60
60-64	.88906	.11094	6 873	61 953	292 583	1 159 675	18.72	2.62
65-69	.89245	.10755	5 924	55 080	260 590	867 092	15.74	2.66
70-74	.84016	.15984	7 857	49 156	226 138	606 502	12.34	2.78
75 +				41 299	380 364	380 364	9.21	3.06

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .820 Corresponding e(75) = 9.21

Table 4.20 Life Table Eliminating Blood Diseases as A Cause of Death for the Total Female Population in Kenya (Multiple Decrement) and the Corresponding Gain in Life Expectancy at Each Age

Age Group	$_n\bar{P}^i_x$	$_n\bar{Q}^i_x$	$_n\bar{d}^i_x$	$\bar{\ell}^i_x$	$_n\bar{L}^i_x$	$\bar{T}^i_x$	$\bar{e}^i_x$	$\bar{e}^i_x - e_x$
0-4	.86902	.13098	13 098	100 000	467 255	5 849 348	58.49	2.76
5-9	.98050	.01950	1 695	86 902	430 273	5 382 093	61.93	2.50
10-14	.98806	.01194	1 017	85 207	423 493	4 951 820	58.12	2.46
15-19	.98530	.01470	1 238	84 190	417 855	4 528 327	53.79	2.42
20-24	.98101	.01899	1 575	82 952	410 823	4 110 472	49.55	2.38
25-29	.97612	.02388	1 943	81 377	402 030	3 699 649	45.46	2.35
30-34	.97417	.02583	2 052	79 435	392 045	3 297 619	41.51	2.32
35-39	.96700	.03300	2 554	77 383	380 530	2 905 574	37.55	2.32
40-44	.97012	.02988	2 236	74 829	368 555	2 525 044	33.74	2.32
45-49	.95903	.04097	2 974	72 593	355 530	2 156 489	29.71	2.32
50-54	.94201	.05799	4 037	69 619	338 003	1 800 959	25.87	2.32
55-59	.94238	.05762	3 779	65 582	318 463	1 462 956	22.31	2.35
60-64	.88271	.11729	7 249	61 803	290 893	1 144 493	18.52	2.42
65-69	.88439	.11561	6 307	54 554	257 003	853 600	15.65	2.57
70-74	.83464	.16536	7 978	48 247	221 290	596 597	12.37	2.81
75 +				40 269	375 307	375 307	9.32	3.17

$_{30}\bar{d}^i_{10}/_{20}\bar{d}^i_{40}$ = .797   Corresponding e(75) ≃ 9.32

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CHAPTER V

CONCLUDING SUMMARY AND RECOMMENDATIONS:

5.1 INTRODUCTION

The main objectives of this study were:

1) To estimate the completeness of death registration in Kenya in 1979 relative to the 1979 census population enumerated by age and sex - using the Bennett-Horiuchi method;

2) To construct life tables for Kenya in 1979 using the 1979 number of registered deaths by age and sex - using the Bennett-Horiuchi method of constructing life tables from incomplete death registration data;

3) To construct life tables for Kenya in 1979 using only the 1969 and 1979 censuses data - by the Preston Census - based method; and finally,

4) To construct life tables by groups of causes of death - using the single and multiple decrement approach.

In order to accomplish the above mentioned objectives, the study was divided into five chapters. Chapter One mainly deals with the Problem Statement, Objectives, Theoretical Statement, hypotheses and the literature review. In Chapter Two, the methods of analysis are mathematically derived and discussed. In Chapter Three, three of the four methods of analysis derived and discussed in Chapter Two are applied to study the completeness of death registration in Kenya and to construct life tables for Kenya in 1979 using the number of registered deaths; and using the 1969 and 1979 censuses data respectively. In Chapter Four, the single and multiple decrement approaches derived and discussed in Chapter II are applied to the mortality data in Kenya in 1979 registered by cause, age and sex. Finally in this Chapter, a summary of the major findings is given followed by revelation of the limitations of the various methods of analysis. In the final section of this chapter, recommendations for policy planners and for further research will be given.

5.2 CONCLUDING SUMMARY

A study of the completeness of death registration has revealed that registration of deaths in Kenya is poor for both males and females, and that male deaths are reported relatively better to female deaths. The completeness was only .222 for males and .127 for females in 1979. That is to say, out of all males deaths which occurred in

1979, only 22.2 per cent of the deaths were currently reported. Similarly, for females, out of all deaths which occurred in 1979 only 12.7 per cent of the deaths were reported or registered.

A study of the life expectancy estimates for Kenya obtained by the Bennett-Horiuchi method and the Preston census-based method shows that the two methods give estimates which appear acceptable as nearly all of them decline with increase in age. A comparison of the two sets of life expectancy estimates due to the two methods reveals that below age 35 years for males and age 45 years for females, the life expectancy estimates due to the Bennett-Horiuchi method are systematically relatively higher than the corresponding estimates due to the Preston census-based method. And from age 35 years for males and age 45 years for females onwards, the pattern changes, i.e.; the life expectancy estimates due to the Bennett-Horiuchi method become systematically relatively lower than the corresponding estimates due to the Preston census-based method.

Further, a comparison of the life expectancy estimates due to the two methods of constructing life tables and the corresponding values in the Kenya National "Model" life tables 1979 revealed that the life expectancy estimates due to the Bennett-Horiuchi method agree relatively better with the corresponding Kenya National "Model" life table values than the corresponding life expectancy estimates due to the Preston census-based method.

On the basis of the foregoing findings we conclude that the Bennett-Horiuchi method of constructing life tables from incomplete death registration data gives better life expectancy estimates relative to the Preston census-based method.

On Cause of death analysis, the study has found that there exists age, sex and cause of death mortality differentials; with mortality estimates due to the single decrement approach being relatively higher than the corresponding multiple decrement estimates. And that for a given cause of death, the mortality patterns due to the two methods are similar. Further, for all groups of causes considered except accidents, the risk of dying is always high at the beginning and at the end of the life span; lowest at puberty, and low with an upward slope during the long period of adulthood. For accidents the risk of dying is higher during the active years of life.

During the early years of life, it is observed that the major causes of death for both males and females were Infective - Parasitic and respiratory diseases. Between ages 15 years and 45 years, the effect of accidents as a cause of death becomes great. It claimed a heavy toll of lives for males between the two ages.

In order to have a general picture of the cause of death structure by age and sex, the population can be sub-divided into three broad age groups:
Under 15 years of age, 15 years to 45 years, and 45 years and over. For males below age 15, the leading causes of death are: Infective and Parasitic, respiratory and circulatory system diseases. Between ages 15 years, and 45 years the three leading causes in order are: accidents, Infective and Parasitic, and circulatory system diseases. Thereafter, the leading causes are infective and parasitic, circulatory system diseases and respiratory system diseases.

Among females, although the order is not clear below age 15, the three leading causes of death in order can be said to be Infective and Parasitic, respiratory system diseases and circulatory system diseases. Between ages 15 years and 45 years, the leading causes are infective and parasitic, circulatory system diseases and accidents. And thereafter, the leading causes are infective and parasitic, circulatory system diseases and respiratory system diseases.

The mortality estimates further indicate excess female mortality over male mortality at the early years of life. This could be due to "in-born" biological (demographic) factors.

On the basis of the foregoing findings, it is concluded that as in many developing countries, the major causes of death in Kenya as revealed by the 1979 registered deaths data are basically environmental causes.

5.3 LIMITATIONS OF THE METHODS OF ANALYSIS:

Although the methods of analysis used in this study have given reasonably good results, they however have some limitations which we shall just outline at this stage, Method by Method.

Starting with Method I, Bennett-Horiuchi Method of estimating the completeness of death registration, the the limitations include the following:

First, if the extent of migration is significantly large compared to the number of registered deaths the estimated completeness tends to be biased upward in the presence of net out-migration and downward by net in-migration.

Second, the method is based on the assumption that the underregistration of deaths is independent of age, at least for adults. However, the completeness may sometimes differ with age.

Finally, this method may be sensitive to the differential enumeration of the two successive censuses from which the annual age specific growth rates are calculated. Relative underenumeration in first (Second) census would raise (lower) age specific growth rates and thereby bias the estimated completeness of death registration.

Of the above mentioned limitations, note that no <u>prior</u> adjustment was made in this study for the substantial influx of Ugandans to Kenya during the Amin regime and/or during the 1979 liberation war in Uganda, and the believed differential coverage of the 1969 and 1979 Censuses.

For the Bennett-Horiuchi Method of constructing life tables from incomplete death registration data, its main drawback is:

No estimate of the life expectancy at birth is made using this method since it is likely that deaths under age five are recorded to a lesser extent than those above age five. Life expectancy under age five should therefore be estimated through some other method of estimating infant and childhood mortality.

For the Preston census-based method of constructing life tables, its major drawbacks are:

First, the mortality estimations obtained are sensitive to differential degrees of coverage obtained by two successive censuses.

Second, the estimations are sensitive to intercensal migration.

Finally, the mortality estimations obtained by this method fail to represent effectively mortality conditions in the first five years of life. Therefore like the Bennett-Horiuchi Method of constructing life tables, for a complete representation of mortality conditions in developing countries (Kenya included), it will also usually be necessary to introduce additional information of childhood mortality levels.

For the single and multiple decrement methods of cause of death analysis, their main drawback is that the methods use the mortality estimations due to the Bennett-Horiuchi method of constructing life tables as intermediate results in making cause of death mortality estimations. Thus, errors in the estimations due to the Bennett-Horiuchi Method are likely to be transferred into the cause of death mortality estimations.

5.4 RECOMMENDATIONS

5.4.1 Recommendations for Policy Planners:

On the basis of the above conclusions, the completeness of death registration is poor and for the few deaths registered, cause of death data is not readily available. For instance this study has only analysed the 1979 registered deaths, but it is for years since these deaths were registered and yet, they could not be obtained easily. It took the researcher over eight months to get the data. It is therefore recommended that the authorities concerned with the registration of deaths should urge the staff at health Centers and hospitals where some deaths occur to step up efforts in reporting the deaths completely and accurately. Also, Chiefs and their Assistants whose assistance the government has sought in the registration of vital events should be taught and be informed of the importance of the exercise and be asked to register all deaths completely and accurately (that is by cause, age, sex and other related characteristics). Since it is however a bit hard for a layman to know the cause of death precisely, it is suggested that before any burial ceremony takes place, every death should undergo a Postmoterm to ascertain the cause of death.

The available cause of death data though poor has revealed that, although there has been substantial mortality declines in Kenya over the recent past, which have been attributed due to socio-economic development and technological advances in the prevention and control of diseases, and the growth and expansion of public health and, medical services, many groups of causes of death that still take a heavy toll of lives comprise diseases that can be treated easily if curative services were readily available to the households; a range of the diseases common to the population could be prevented through immunization. It is against this background that the study recommends that immunization should be brought to the households. Further, since many infections and parasitic diseases can be directly or indirectly associated with malnutrition, in particular among children, effective suppression is not amenable to the medical solution alone. It is therefore recommended that household living standards, should be improved and better education concerning hygiene and nutrition be provided; more particularly to mothers.

Finally, strict laws to prevent accidents should be formulated and implemented to arrest the rising number of deaths due to accidents during the active years of one's life span.

5.4.2 Recommendations for Further Research:

This study has confirmed that the major causes of death in Kenya are environmental in origin; there is therefore need for studies to determine regional differences in prevalence of causes of death since Kenya is ecologically and climatically a diverse country. This will particularly help Health Planners in the distribution of the scarce medical facilities and services.

Further, the cause of death categories employed in this study are too broad to provide an adequate basis for formulating a concrete public health policy in regard to specific diseases, it is therefore recommended that studies should be carried out to determine which diseases among the leading groups of causes of death are most prevalent in Kenya and by region.

APPENDIX OF TABLES

Table A.1 (i)

The ratio, ${}_{30}d_{10}/{}_{20}d_{40}$, and corresponding e(x) values (x=75,...,95) associated with many levels of mortality in the Coale-Demeny West model life tables, males and females.

MALES

Level	Ratio	e(75)	e(80)	e(85)	e(90)	e(95)
3	1.161	6.05	4.55	3.35	2.41	1.71
4	1.094	6.31	4.75	3.49	2.51	1.77
5	1.034	6.57	4.95	3.63	2.60	1.83
6	.980	6.82	5.14	3.77	2.70	1.90
7	.930	7.06	5.32	3.90	2.79	1.95
8	.885	7.29	5.49	4.03	2.87	2.01
9	.842	7.52	5.67	4.15	2.96	2.07
10	.802	7.74	5.83	4.27	3.04	2.12
11	.763	7.96	5.99	4.38	3.12	2.18
12	.725	8.17	6.15	4.50	3.20	2.23
13	.689	8.38	6.30	4.61	3.28	2.28
14	.648	8.55	6.43	4.70	3.34	2.32
15	.609	8.71	6.55	4.79	3.40	2.36
16	.570	8.88	6.68	4.88	3.47	2.40
17	.530	9.06	6.81	4.98	3.53	2.45
18	.490	9.26	6.95	5.09	3.61	2.50
19	.447	9.46	7.11	5.20	3.68	2.55
20	.401	9.67	7.26	5.31	3.77	2.60
21	.352	9.90	7.43	5.44	3.85	2.66
22	.305	10.25	7.70	5.63	3.99	2.75
23	.255	10.70	8.03	5.88	4.16	2.86
24	.202	11.28	8.48	6.21	4.40	3.02
25	.147	12.06	9.08	6.66	4.71	3.23

FEMALES

Table A.1 (ii)

Level	Ratio	e(75)	e(80)	e(85)	e(90)	e(95)
2	1.461	6.15				
3	1.376	6.45	4.88	3.57	2.54	1.78
4	1.300	6.75	5.11	3.73	2.65	1.86
5	1.233	7.05	5.33	3.89	2.76	1.93
6	1.171	7.34	5.54	4.04	2.87	1.99
7	1.115	7.62	5.75	4.19	2.97	2.06
8	1.062	7.89	5.95	4.33	3.07	2.12
9	1.012	8.16	6.14	4.47	3.16	2.19
10	.964	8.42	6.33	4.61	3.26	2.25
11	.918	8.67	6.52	4.74	3.35	2.31
12	.372	8.92	6.70	4.88	3.44	2.37
13	.827	9.17	6.88	5.00	3.53	2.43
14	.787	9.37	7.02	5.11	3.60	2.47
15	.729	9.56	7.16	5.21	3.67	2.52
16	.673	9.77	7.32	5.33	3.75	2.57
17	.617	9.99	7.48	5.44	3.83	2.63
18	.660	10.23	7.65	5.57	3.92	2.68
19	.501	10.48	7.83	5.70	4.01	2.74
20	.488	10.73	8.01	5.84	4.11	2.80
21	.365	11.01	8.22	5.99	4.21	2.87
22	.298	11.44	8.54	6.22	4.38	2.98
23	.235	11.97	8.94	6.62	4.69	3.12
24	.175	12.65	9.46	6.91	4.86	3.10
25	.117	13.52	10.17	7.45	5.24	3.84

Source: Bennett N.G. and S. Horiuchi, 1982 op. cit., pp 11.

Table A.2 Coefficients for Estimating ρ(A) from the Growth Rate over Age 10 and the Ratio of the population over age 45 to the population over age 10.

Estimating equation:

$$\rho(A) = a(A)+b(A)r(10+) + C(A)\ln[N(45+)/N(10+)]$$

(1) Age	(2) a(A)	(3) b(A)	(4) C(A)
45	.229	20.43	.258
50	.205	18.28	.235
55	.179	16.02	.207
60	.150	13.66	.176
65	.119	11.22	.141
70	.086	8.77	.102
75	.053	6.40	.063
80	.025	4.30	.029
85	.006	2.68	.006

Source: Hill, K and H. Zlotnik, 1982 op. cit. pp. 5

Table A.3 Coefficients for Estimating Z(A) from the Ratio of Deaths 45+ to Deaths 10+ and the Population Growth Rate.

1 Regional Family	2 A	3 a(A)	4 b(A)	5 C(A)
West	45	-13.43	181.4	17.57
	50	-12.49	163.6	15.49
	55	-11.24	143.7	13.34
	60	- 9.50	121.2	11.07
	65	- 7.21	96.1	8.67
	70	- 4.48	69.2	6.23
	75	- 1.64	42.9	3.91
	80	- .72	20.5	1.98
	85	2.03	5.9	.70

Source: Hill, K and H. Zlotnik, 1982 op. cit. pp 21.

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