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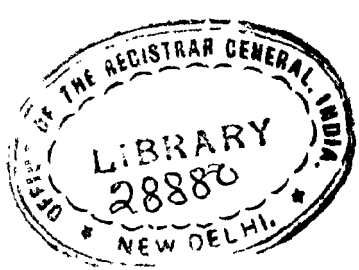
SUMMARY REPORT ON TRAINING WORKSHOP ON ANALYSIS OF FERTILITY AND MORTALITY

(New Delhi, July 29—August 16, 1991)

Office of the Registrar General and Census Commissioner, India
Ministry of Home Affairs
New Delhi

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PREFACE

Under the agreement on Family Planning Communications and Marketing between the Government of India and the United States of America through the Agency for International Development (USAID), the Demographic Analysis Component has been assigned to the Office of the Registrar General, India to execute. Activities under the component include training, workshops, conferences and research activities in collaboration with the East-West Population Institute (EWPI), East-West Center, Honolulu, Hawaii and the Bureau of the Census (BUCEN), Washington, D.C.

Under this programme of activities, a training workshop on analysis of fertility and mortality was conducted in the Office of the Registrar General, India, New Delhi during July 29 to August 16, 1991 in collaboration with EWPI. The main objective in conducting this training workshop was to expose a group of selected officials of the organisation to current knowledge and practice of the techniques of demographic analysis. With increasing use of personal computers in data analysis in modern times, it was decided to train the participants in the workshop in the use of personal computers also. This volume contains a brief report on the workshop.

I take this opportunity to thank USAID and EWPI for their co-operation in running this workshop and for providing pocket calculators and personal computers for the use of the participants. I am grateful to Dr. Robert Retherford and Dr. Norman Luther, experts from EWPI for their lectures and continuous guidance to the participants in the workshop, sometimes going beyond the working hours.

Shri K. S. Natarajan, Deputy Registrar General (Demography Division) and Shri N. Rama Rao, Deputy Registrar General

(Census and Tabulation) functioned as coordinators for the workshop, ably assisted by Shri K. N. Unni, Senior Research Officer. I had the assistance of Shri P. D. Joshi, Senior Research Officer in the preparation of this report. My thanks are due to them, the participants and other colleagues who spared no pains in making the workshop a success.

A. R. Nanda
Registrar General and
Census Commissioner, India

New Delhi
December 31, 1991.

Summary Report on the Training Workshop on Analysis of Fertility and Mortality

(New Delhi, July 29—August 16, 1991)

The names of the coordinators, guest lecturers and participants in the workshop are given in Annexe I. The programme of the workshop is given in Annexe II.

The purpose of this workshop was to train a group of selected officers with background in mathematics or statistics from the Office of the Registrar General, India and the Directorates of Census Operations in indirect techniques of fertility and mortality estimation and population projection. It was also aimed at acquainting the participants with the use of personal computers (PCs) and selected software packages for some of the basic demographic methods.

The topics covered in the workshop were by no means exhaustive in fertility and mortality analysis. These were designed to expose the participants to some of the latest techniques of demographic analysis and use of PCs for the same. It was expected that this training would encourage the participants to continue this analysis when they got back to their respective offices.

Generally, lectures and demonstrations were given each morning. Afternoons were spent in doing exercises and practising the methods and computer programmes presented earlier.

The lectures by Dr. Robert Retherford and Dr. Norman Luther included: Lexis Diagrams, Life Tables including model life tables, the concept of stationary population, fertility estimation using the P/F ratio method, the parity increment method, and the own-children method; indirect child mortality estimation using Brass's method, population projection by the cohort-component method including migration. The lecture notes which will give a broad idea of these topics are given in Annexe III.

On August 2, Shri K. S. Natarajan, Deputy Registrar General, India, gave a lecture on the fertility and child mortality estimation from the census data. On August 13, Shri V. S. Swamy, Deputy Registrar General (Vital Statistics) spoke on estimation of fertility and mortality from the data of the Sample Registration Systems (SRS) implemented by the Office of the Registrar General, India. The summaries of their lectures may also be found in Annexe III.

After the methodology, underlying assumptions and analytical pitfalls were presented in lectures for each method, participants were given exercises with special reference to census data of India/States/Union Territories, and data from SRS and the 1972 survey of fertility and mortality. Initially, pocket calculators were used for doing the exercises which were designed to test understanding of the methods. Only then did participants proceed to learn how to use computer programmes for these methods that were implemented on six PCs rented for the workshop. The list of software for PCs used in the workshop is given in Annexe IV.

The six PCs and three printers hired were shared by sixteen participants. On the last day, there was a discussion about how each participant could use the programmes when they returned to their respective offices.

Most of the participants had never worked on PCs before. The workshop provided a unique opportunity to the participants in the use of PCs for demographic methods under the guidance of experts in the field. That the participants were enthusiastic throughout was evident from the use they made of the PCs even beyond the workshop hours.

ANNEXE-I

COORDINATORS, GUEST LECTURERS AND PARTICIPANTS OF TRAINING WORKSHOP ON ANALYSIS OF FERTILITY AND MORTALITY

Coordinators

East-West Population Institute

1. Dr. Robert Retherford
2. Dr. Norman Luther

Office of the Registrar General, India

1. Shri K. S. Natarajan,
   Deputy Registrar General (Demography)
2. Shri N. Rama Rao
   Deputy Registrar General (Census and Tabulations)

Guest Lecturers

1. Shri K. S. Natarajan
   Deputy Registrar General (Demography)
2. Shri V. S. Swamy
   Deputy Registrar General (Vital Statistics)

Names and Designations of the Participants

Name	Designation
1. Bhati, Mahendra Singh . .	Investigator, Census Division, ORGI
2. Ghosh, Amiya Kumar . .	Assistant Director of Census Operations, Office of the DCO West Bengal, Calcutta
3. Hossain, S.M. Nehal . . .	Assistant Director of Census Operations, Office of the DCO Bihar, Patna
4. Joshi, Prabhakar Diwakar . .	Senior Research Officer, Vital Statistics Division, ORGI

Names and Designations of the Participants—*Concld.*

Name	Designation
5. Kamalam, C.	Assistant Director of Census Operations, Office of the DCO, Thiruvananthapuram
6. Lakshmi Narayanan, R. . .	Investigator, Office of the Director of Census Operations, DCO, Tamil Nadu, Madras
7. Lakshmipati Sastry, V. . .	Assistant Director of Census Operations, Office of the DCO, Andhra Pradesh, Hyderabad
8. Malhotra, (Mrs.) Bimla . .	Assistant Director of Census Operations, Vital Statistics Division, ORGI
9. Nigam, Amena	Investigator, Office of the DCO, Uttar Pradesh, Lucknow
10. Om Prakash	Investigator, Vital Statistics Division, ORGI
11. Pongurlekar, R.N. . . .	Assistant Director of Census Operations, Office of the DCO, Maharashtra, Bombay
12. Roy Choudhury, Abhijit . .	Assistant Director of Census Operations, Office of the DCO, Arunachal Pradesh
13. Sharma, Pran Nath . . .	Investigator, Demography Division, ORGI
14. Sinha, Dinesh Prasad . . .	Investigator, Office of the DCO, Uttar Pradesh, Lucknow
15. Soam, Niranjan Singh . . .	Assistant Director of Census Operations, Social Studies Division, ORGI
16. Tripathy, Prasad . . .	Assistant Director of Census Operations, Office of the DCO, Orissa, Bhubaneshwar

ANNEXE-II

PROGRAMME OF THE WORKSHOP

Daily Timings: 10:00—11:15; Tea break; 11:30—1:15
Lunch break
2:30—3:45; Tea break; 4:00—5:15

Opening remarks, Inaugural Session. Monday, July 29, 10:00 A.M.

A. R. Nanda
Robert Retherford
Norman Luther
Introduction of participants

TOPICS:

July 29, Monday

Lexis diagrams

Distribute: 1. MORTPAK manual and diskette
2. EASWESPOP manual and diskette
3. FIVFIV-SINSIN manual and diskette
4. Handout on Lexis diagrams
5. Problem set on Lexis diagrams

July 30, Tuesday

Life tables
Discussion of data on children ever born

Distribute: 1. Handout on life tables
2. Problem set on life tables
3. Handout on children ever born (Manual 10)
4. Handout on fertility estimation methods

July 31, Wednesday

Life tables, including model life tables (continued)
Stationary population

Distribute: 1. Handout on stationary population
2. Problem set on survival ratios and reverse-survival ratios

August 1, Thursday

Stationary population (continued)

P/F ratio methods

Introduction to PCs

August 2, Friday

Children-ever-born and children-surviving data in India (K. S. Natarajan)

P/F ratio methods (continued)

Life tables (using MORTPAK program)

August 5, Monday

P/F ratio methods (continued)

Parity-increment method

August 6, Tuesday

P/F ratio methods (continued)

Parity-increment method (continued)

Child mortality estimation

Distribute: Handout on child mortality estimation

August 7, Wednesday

Child mortality estimation (continued)

Own-children method of fertility estimation

Distribute: Handouts on own-children method

August 8, Thursday

Child mortality estimation (continued)

Own-children method (continued)

Distribute: 1. Handout on population projections

2. Problem set on own-children method

August 9, Friday

Child mortality estimation (continued)

Own-children method (continued)

Population projections

August 12, Monday

Own-children method (continued)

Population projections (continued)

August 13, Tuesday

Fertility and mortality estimation from the Sample Registration System (V.S. Swamy)

Population projections (continued)

August 14, Wednesday

Completion of Computer work

August 15, Thursday

Holiday

August 16, Friday

Concluding Session

ANNEXE-III

LECTURE NOTES OF EWPI EXPERTS AND GUEST LECTURERS

A. Lecture Notes of EWPI Experts and Guest Lecturers

1. LEXIS DIAGRAMS

Note: The sections of life lines, sets of persons and sets of events are adapted from a handout by Griffith Feeney, dated 2/73.

A Lexis diagram is a graphic portrayal of population and demographic events in the age-time plane, as shown in Figure 1. On the horizontal time axis, the inner set of labels refers to exact dates (January 1 of each year). The outer set of labels refers to entire calendar years. Likewise, on the vertical axis, the inner set of labels refers to exact ages. The outer set of labels refers to age in completed years.

The age axis in Figure 1 is drawn as pointing upward; many texts, however, draw it alternatively as pointing downward. To see the alternative representation, turn page 1 upside down and view it from the back side against a light.

Life lines

The life history of any person in the population may be represented as a line segment which begins at the point (a_1, t_1), denoting the exact age and time at entrance to the population, and ends at the point (a_2, t_2), denoting the exact age and time at exit from the population. Entrance or exit occurs through acquisition or loss of some defining characteristic of the population. The defining characteristic might be the mere fact of being

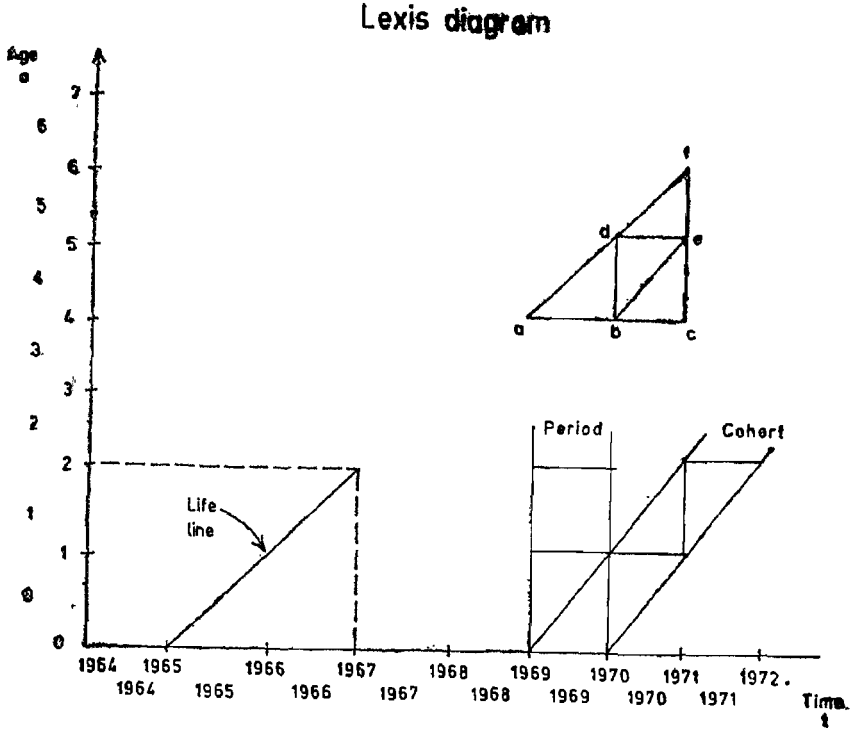


Figure 1

alive, in which case entrance is defined by birth and exit by death. If the state of being currently married is the defining characteristic, entrance is defined by the act of marriage, and exit by any event causing cessation of marriage. Such a line segment connecting the points (a_1, t_1) and (a_2, t_2) is called a **life line**. If age and time are depicted in common units (years, in Figure 1), life lines incline upward to the right at an angle of 45 degrees from the horizontal.

Sets of persons

Imagine that we have drawn on the age-time plane of Figure 1 the life lines of all persons who were ever in a given population. A particular person is in the population at time t if and only

if this person's life line intersects the vertical line extending upward from the point t (say January 1, 1968) on the time axis. The set of all persons in the population at time t is, accordingly, the set of all persons whose life lines intersect this vertical line, and this line may be thought of as representing this set of persons.

More generally, any line segment in the age-time plane may be thought of as representing the set of persons whose life lines intersect this segment. The two most useful examples are horizontal line segments, which represent sets of persons attaining some exact age during a given time period and vertical line segments, which represent sets of persons in a given age interval at some point in time. Note that we never actually draw all the life lines for the population. We imagine them drawn, and then apply the representation principle.

Sets of events

The age-time coordinates of any demographic event may also be plotted in the Lexis diagram of Figure 1. As with life lines, we may imagine plotting the position of every death (or birth, or other event) to a particular population during a given time period as a point in the age-time plane of Figure 1. A particular death occurs during the time period (t, t+n) if and only if its plot lies within the strip of the aga-time plane formed by the vertical lines extending upward from these two points on the time axis. This area may, accordingly, be thought of as representing the set of all deaths to the population during the time period (t, t+n).

More generally, any area in the age-time plane may be thought of as representing the set of deaths (or other events) whose age-time coordinates lie within the area. The following examples refer to Figure 1. The rectangle bcde represents the set of deaths between January 1, 1970, and January 1, 1971, to persons between exact ages 4 and 5. The parallelogram abed represents the set of deaths occurring between exact ages 4 and 5 to persons who attained exact age 4 between January 1, 1969 and January 1,

1970. The parallelogram befd represents the set of deaths occurring between January 1, 1970, and January 1, 1971, to persons whose exact age on January 1, 1970 was between 4 and 5.

Period data vs. cohort data

The Lexis diagram in Figure 1 also portrays graphically the distinction between period data and cohort data. Period data, which provide information on persons or events by age for a fixed time period, are represented by a vertical line or column in the a--t plane. Cohort data, which provide information on the life history of a real group of persons in the population, are represented by a cohort corridor that inclines upward to the right at an angle of 45 degrees. Period data are sometimes interpreted as representing the life history of a hypothetical cohort that lives out its existence according to age-specific frequencies of events specified by the period data.

In some countries, such as France, government statistics generally classify persons not only by age in completed years but also by year of birth. This double classification of persons allows persons to be grouped into birth cohorts, and events, (e.g., births) to be assigned to triangles and parallelograms along cohort corridors in the a—t plane. Double classification thus facilitates cohort analysis of demographic data.

In most countries, however, including the United States, official statistics normally classify persons only by completed years of age. While this results in obvious economy in publication, it makes cohort analysis somewhat awkward.

The person-years concept

The concept of person years parallels the concept of man-hours of work. If two men work for three hours, they collectively accomplish $2 \times 3 = 6$ man-hours of work. Similarly, if two persons live three years each, they live a total of six person-years,

during which they may be exposed to the risk of certain demographic events, such as birth, death, or marriage. Demographers often think of person-years as exposure.

Person-years may be portrayed graphically by means of Lexis diagrams. Consider any area within the a—t plane. Person-years lived within this area are simply the sum of the horizontal or vertical projections of all life lines within the area. More economically, we can simply think of the area itself as representing person-years lived within the area: again we only imagine the life lines and their projections without actually drawing them in.

Of course, government statistics do not present data for each individual, so in practice it is not possible to calculate person-years directly from individual life lines. The usual procedure is to assume that over a small symmetrical area in the a—t plane, such as a square or parallelogram, exits from the population are evenly distributed, so that person-years for the area may be approximated by the mid-period population multiplied by an appropriately chosen average time duration.

Rates, expectations and probabilities

The numerator of a demographic rate is number of events, say deaths, and its denominator is person-years of exposure. The numerator of an *expectation or probability* is again number of events, but its denominator is initial population at risk. An expectation is a probability if its theoretical upper limit is unity (which is not always true of birth expectations, for example, since for periods longer than one year, substantial numbers of women have more than one birth).

We distinguish several types of rates, expectations and probabilities. For purposes of illustration we consider only the simple single-year areal configurations of population and death events shown in Figure 2. We have the following definitions, based on Figure 2:

A. Rates

1. Age-cohort death rate: d_1/e_1
2. Central death rate: d_2/e_2
3. Time-cohort death rate: d_3/e_3

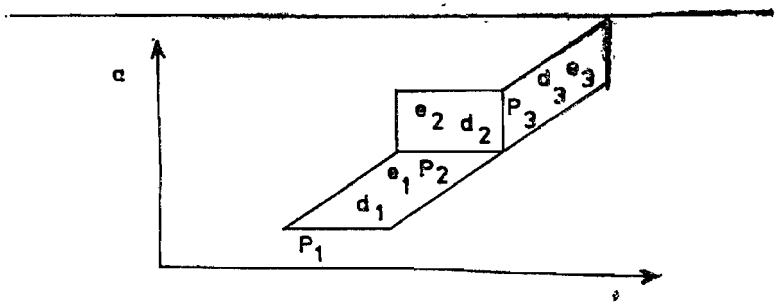


Figure 2: Graphical portrayal of population (p), exposure (e), and deaths (d) for three types of areas in the a-t-plane.

B. Expectations and probabilities

1. Age-cohort expectation or probability: d_1/P_1
2. Time-cohort expectation or probability: d_3/P_3

As is apparent from Figure 2, an age-cohort parallelogram defines initial population at risk at an exact age. A time-cohort parallelogram defines initial population at risk at an exact time. In all cases exposure is commonly approximated by mid-period population, represented as a vertical line through the middle of each of the three areas. Were the figure drawn for time periods of more than one year, exposure would be approximated by mid-period population multiplied by an appropriate time duration greater than one year.

2. STATIONARY POPULATION

Note: This note covers the concept of a stationary population as well as applications to (1) the link between life table probabilities of dying ${}_nq_a$ to observed age-specific death rates ${}_nM_a$, and (2) population projections by age. The first two sections incorporate elements of a handout on stationary populations written by Griffith Feeney, dated 1/74.

Introduction

In the previous note on life tables, we viewed the life tabls as a life history of a particular birth cohort of, say, 100,000 births. Nothing was said about the time distribution of these births. One could think of them as all occurring at the same instant of time or spread out evenly or unevenly over any number of calendar years.

Under certain assumptions about the time distribution of births and the constancy of mortality, the life table L_a column may be interpreted as the relative age distribution of a **stationary population.** A stationary population is defined as any population in which births are uniformly distributed in time and in which every birth cohort exhibits the same age-specific mortality.

The fundamental theorem of stationary population theory states: In a stationary population, the number of persons aged a to a+n at any given time equals the number of person-years lived between ages a and a+n by the persons born during any one year period.

Proof: A thorough proof of this theorem requires some effort and mathematical sophistication. We first consider a simplified proof based on Lexis diagrams.

Lexis diagram of a stationary population

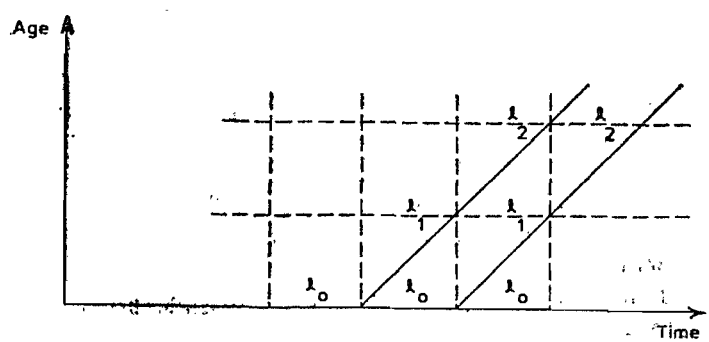


Figure 1

In Figure 1 l_0 births occur every year and are spread evenly over the year. Of these, l_1 survive to exact age 1, l_2 to exact age 2, etc. Consider the two triangles between l_1 and l_2 in the cohort corridor drawn in the figure. It is approximately true that one-half the deaths between exact ages 1 and 2 occur in each triangle. Hence the mid-period population is $.5\ (l_1+l_2)$. But this is equal to L_1, proving the theorem for the age group 1 to 2. The proof for other ages groups (except 0 to 1) is similar. (The 85+ group may be thought of as a sum of single-year age groups to which the above reasoning applies, terminating at the oldest age w.)

For those familiar with calculus, a more rigorous proof, which applies to the first as well as subsequent age groups, is as follows. The number of persons aged z to z + dz at time t equals the number of persons born between times t—z and t—z—dz, namely $l_0\ dz$, times the proportion of those persons who survive to age z, l_z/l_0 (dz is the width of an infinitesimally small time interval). The total number of persons aged a to a+n equals the sum of these products over all z between a and a+n. Hence the number of persons aged a to a+n is

$$\int_a^{a+n} l_0\ (l_z / l_0)\ dz$$

But this equals

$$\int_a^{a+n} l_z\ dz,$$

which is by definition the number of person-years lived between ages a and a+n by the persons born in any one-year period.

This proof, depending as it does on the fiction of births continuously distributed in time, is not entirely convincing. It would be more realistic to speak of the *risks* of birth and death being evenly distributed through time and age, respectively, rather than the events themselves. Only when a discrete and stochastic, as opposed to continuous and deterministic, approach

is developed can the fundamental theory be put on a firm basis. It turns out that the above statement of the theorem is valid for expected values and can be rigorously demonstrated. However, we shall not pursue the stochastic approach in this course.

Properties of stationary populations

The most elementary consequence of the fundamental theorem is that the number of persons in any age group is constant over time. In particular, total population size is constant and equal to T_0 the total number of person-years lived by any annual birth cohort.

From the constancy of total population and annual births, it follows that the annual number of deaths, like the annual number of births s constant also. The crude death rate is therefore l_0/T_0, which is the reciprocal of life expectancy at birth.

Finally, we prove the following *theorem.* The number of deaths between exact ages a and a+n to persons born during any year equals the number of deaths in any year in which the decedent was aged a to a+n.

Proof: The theorem is equivalent to saying that the number of deaths in an age-cohort parallelogram equals the number of deaths in a square bounded above and below by the same ages, as shown in the following excerpt from a Lexis diagram. We wish to show that the number of deaths in parallelogram abed is the same as the number of deaths in square bced.

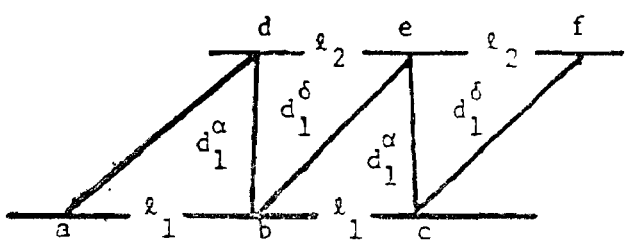


Figure 2

Clearly the number of deaths d_1^{α} in triangle abd equals the number of deaths d_1^{α} in triangle bce. Since triangle bde, with deaths d_1^{δ}, is common to parallelogram abed and square bced, it follows that the number of deaths in parallelogram abed equals the number of deaths in square bced. This completes the proof. This theorem is important for computing life tables from observed central age-specific death rates, as shown in the next-section.

Link between life table $_n\bar{q}_a$ and observed $_nM_a$

To establish a link between $_nq_a$ and $_nM_a$, we assume that to a close approximation the observed population is *sectionally stationary* for any (n+1)-year birth cohort. By this we mean that the Population is stationary within a cohort corridor n+1 years wide in the Lexis plane. For example, for the rate $_2M_0$ (based on deaths in the shaded rectangle in the figure below), the cohort corridor encompassing the rectangle is three years wide. Within the corridor,

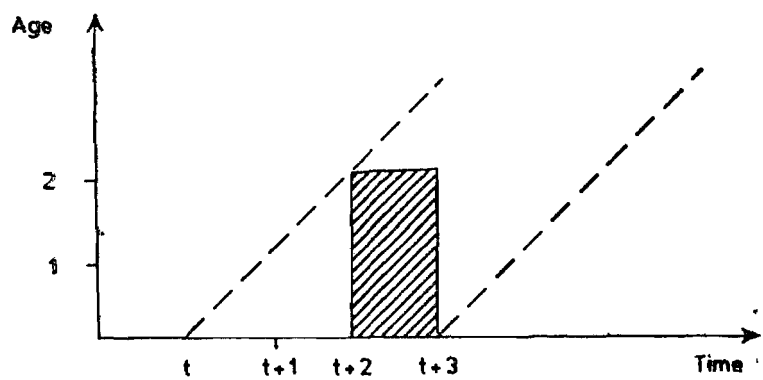


Figure 3

then, the sectional stationarity assumption imposes a kind of smoothing of the data such that births are assumed evenly

distributed between t and t+3, and all persons born in this interval have the same age-specific mortality risks.

We return now to Figure 2. By the theorem of the previous section, it is true in the life table stationary population that the number of deaths d_a in an age cohort parallelogram bounded below and above by ages a and a+1, respectively, equals the number of deaths in a corresponding square bounded by the same ages. It follows that the stationary population single-year central age-specific death rate, m_a, pertaining to the square, is

$$m_a = \frac{d_a}{L_a}$$

By aggregation of squares into rectangles it also follows that

$${}_nm_a = \frac{{}_nd_a}{{}_nL_a}$$

corresponding to a rectangle one year wide and n years high in the Lexis plane.

Invoking the assumption of sectional stationarity over (n+1) -year-wide cohort corridors in the observed population, we establish the basic link between life table parameters and observed rates within a stationary section by equating the observed death rate ${}_nM_a$ to the stationary or life table death rate ${}_nM_a$:

$${}_nM_a = {}_nm_a$$

This becomes

$${}_nM_a = \frac{{}_nd_a}{{}_nL_a} = \frac{{}_nq_a\, l_a}{n l_a + n^2 {}_na_a\, {}_nd_a} = \frac{{}_nq_a\, l_a}{n l_a (1 - {}_nq_a) + n^2 {}_na_a\, {}_nq_a\, l_a}$$

$$= \frac{{}_nq_a}{n - n\,{}_nq_a + n^2 {}_na_a\, {}_nq_a}.$$

from which it follows that

$${}_nq_a = \frac{n\,{}_nM_a}{1 + (n - n^2 \hat{a}_a)\,{}_nM_a}$$

the desired result.

For low-mortality countries (e_0 around 70), ${}_1\hat{a}_0$ is around 0.1. For high-mortality countries (e_0 around 40), ${}_1\hat{a}_0$ is around 0.3. In all countries a value of ${}_4\hat{a}_1=2$ is sufficiently accurate for most demographic applications. Likewise, for ages 5 and over, values of ${}_5\hat{a}_a=2.5$ are sufficiently accurate for most demographic applications.

To complete the link between the life table and observed M_a, we must work out an estimation procedure for L_{85+}. Suppose we assume as an approximation that all deaths after age 85 occur before age 95. If we then assume sectional stationarity over 11-year periods, it follows that $M_{85+}=m_{85+}$ or, equivalently,

$$M_{85+}=\frac{d_{85+}}{L_{85+}}=\frac{l_{85}}{L_{85+}}$$

from which it follows that

$$L_{85+}=\frac{l_{85}}{M_{85+}}$$

the desired result. Although the assumption of sectional stationarity over 11-year periods strains reality a bit, the error introduced is not great, because most deaths beyond 85 occur before age 90. Hence the above estimate of L_{85+} is adequate for most demographic applications.

Population projections by age

In the stationary population an age group of persons ${}_nL_a$ has ${}_nL_{a+m}$ members remaining m years later. The survival ratio is ${}_nL_{a+m}/{}_nL_m$. If we assume sectional stationarity for n-year-wide cohort corridors in the observed population, we may use these stationary population survival ratios to project forward the present population by age. Assuming sectional stationarity in the observed population, it is true for times t and t+m that

$$\frac{{}_nP_{a+m}^{(t+m)}}{{}_nP_a^{(t)}}=\frac{{}_nL_{a+m}}{{}_nL_a}$$

Hence

$$ {}_{n}P_{a+m}^{(t+m)} = {}_{n}P_{a}^{(t)} \, ({}_{n}L_{a+m}/{}_{n}L_{a}) $$

The procedure of course requires assumptions about the future course of mortality and consequent choice of life table.

The logic of the procedure can be clarified with some additional examples. For our first example, suppose that we are given the single-year age group P_1 at the beginning of year t and that we wish to project the number E_2 (E denoting the number at an exact age) among them who will reach their second birthday during year t. The problem is illustrated in the diagram below. Were this same diagram to be drawn for a stationary population.

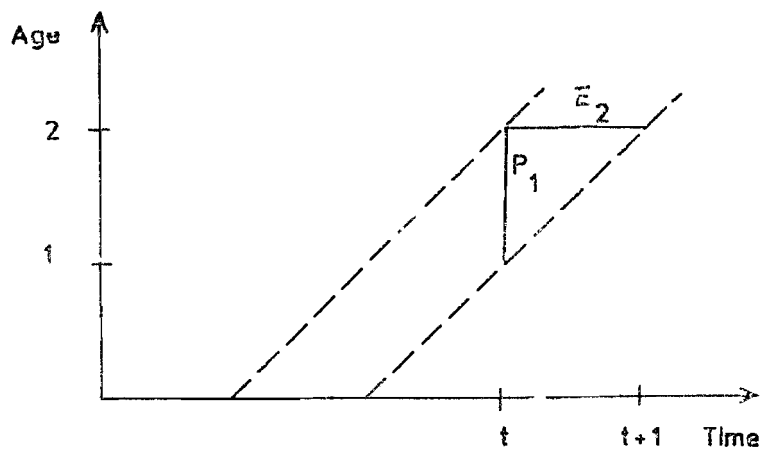


Figure 4

P_1 would be replaced by L_1 and E_2 by l_2. If we assume that the observed population is sectionally stationary within the cohort corridor shown in the diagram, then the ratio of E_2 to P_1 is the same as the ratio of l_2 to L_1. I.e.,

$$ \frac{E_2}{P_1} = \frac{l_2}{L_1} $$

Solving for E_2, we obtain

$$ E_2 = P_1 \, (l_2/L_1) $$

Note that the basic strategy is to equate the ratio of projected value to present value in the observed population to the corresponding ratio in the stationary population, and then to solve for the projected value in the observed population.

As our second example, suppose that we wish to project five years of births between times t and t+5 into the age group 0—4 at time t+5. The problem is illustrated in the diagram below, but this time variables from the stationary population are shown instead of variables from the observed population.

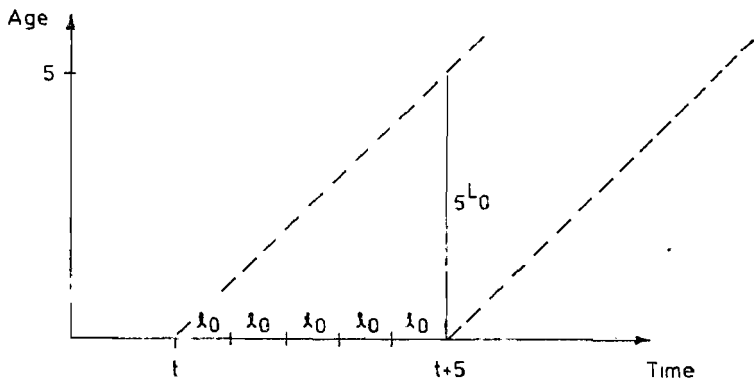


Figure 5

Were this same diagram to be drawn for the observed population, $5\,l_0$ would be replaced by B (five years of births) and $_5L_0$ by $_5P_0$. If we assume that the observed population is sectionally stationary within the cohort corridor shown in the diagram, then the ratio of $_5P_0$ to B is the same as the ratio of $_5L_0$ to $5\,l_0$. I.e.,

$$\frac{_5P_0}{B} = \frac{_5L_0}{5\,l_0}$$

and hence

$$_5P_0 = B(_5L_0/5\,l_0)$$

Again the strategy is to equate the ratio of projected value to present value in the observed population to the corresponding ratio in the stationary population, and then to solve for the projected value in the observed population.

Further notes

As mentioned earlier, the life table can be viewed in two ways: (1) as the life history of a cohort all born at the same instant; (2) as a population, in which births are uniformly distributed in time and in which every birth cohort exhibits the same age specific mortality.

In the first instance, the units of l_a are persons, and the units of ${}_nL_a$ are person-years lived. In the second instance, the units of l_a are persons per year (i.e., persons per year who attain their ath birthday), and the units of ${}_nL_a$ and T_a are persons. You may be interested to know that in other fields (particularly in Physics), analysis in terms of the units or dimensions of quantities is frequently called **dimensional analysis.**

3. LIFE TABLE

A life table is a statistical presentation of the life history of a cohort as it is progressively thinned out by mortality at each age (see displays 1 and 2 at the end of this note.)

Let us suppose that the data P_0, P_1, ..., P_{85}, $P_{85}+$ are given in the following form:

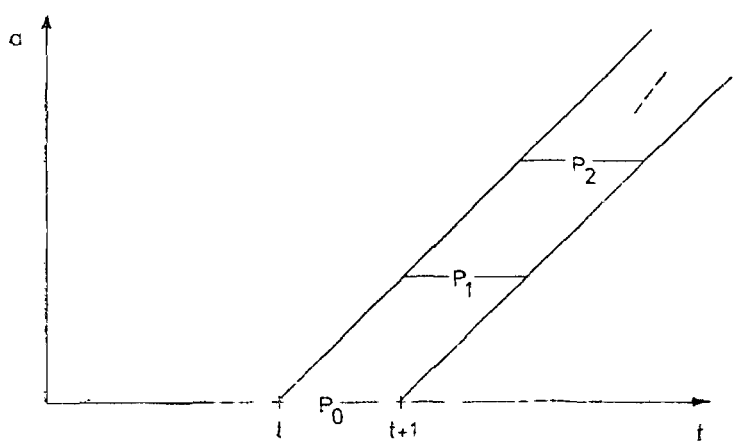


Figure 1

We assume that the population is closed to migration. P_a is the number of persons who reach their a^{th} birthday. P_0 equals B, the initial cohort of births in year t. We derive the average probability of dying between exact ages a and a+1, given survivorship to age a, as

$$q_a = \frac{p_a - p_{a+1}}{p_a}$$

(this equation is generally valid only when the population is closed to migration). The probability of surviving from age a to a+1 is then

$$p_a = 1 - q_a$$

(Strictly speaking these are only estimates of probabilities. It is never possible to derive underlying probabilities directly from empirical data. However, we shall abide by conventional usage and retain the term probability).

The number surviving at each exact age a in the life table is denoted l_a, which is proportional to P_a in the above diagram. For convenience and ease of comparison with other life tables, the initial number in the life table cohort, l_0, is usually set at 100,000. This number, which is arbitrary and could be set at another value if desired, is called the *radix* of the life table.

We let d_a denote the number of life table deaths between exact ages a and a+1. We then have the following life table relationships :

$$d_a = l_a q_a$$
$$l_{a+1} = l_a - d_a = l_a\, p_a = l_a(1 - q_a)$$

It is apparent from the above formula that if one of the columns l_a, q_a, p_a, or d_a is given, the other three can be calculated.

L_a denotes the number of person-years lived between exact ages a and a+1. We define $\hat{a}_a$ as the average number of years lived between exact ages a and a+1 by those who die in the interval. We have then

$$L_a = l_{a+1} + a_a\, d_a$$

The first term on the right is the number of person-years lived by those who survive the interval. The second term is the number of person-years lived by those who die. For all intervals except the first year of life, it is sufficiently accurate for most purposes to set $a_a = .5$. Then the above formula for L_a reduces to

$$L_a = .5(l_a + l_{a+1})$$

In the first year of life most infant deaths occur in the first month or two. Suppose $a_0 = .3$. Then $L_0 = l_1 + .3d_0$, which reduces to

$$L_0 = .3l_0 + .7l_1.$$

T_a denotes the number of person-years lived after age a. We have that

$$T_a = \sum_{i=a}^{w} \omega L_i = T_{a+1} + L_a \quad ,$$

where ω is the oldest age to which anyone survives.

Life expectancy at age a is defined as

$$e_a = T_a / l_a$$

It is the average number of years lived after age a for those who survive to age a.

Abridged life tables

For most demographic uses, life tables are presented in age groups instead of single years of age. Conventional abridged age groups are 0, 1—4, 5—9, 10—14,....., 80—84, 85+.

For an age group n years wide we have

$${}_nq_a = \frac{P_a - P_{a+n}}{P_a}$$

$${}_np_a = 1 - {}_nq_a$$

$${}_nd_a = l_a \, {}_nq_a$$

$$l_{a+n} = l_a - {}_nd_a = l_a \, {}_np_a = l_a(1 - {}_nq_a)$$

$${}_nL_a = n \; l_{a+n} + {}_na_a \, {}_nd_a$$

In most applications it is sufficiently accurate to set ${}_4\hat{a}_1=2$ and ${}_5\hat{a}_a=2.5$ for $a\geqslant 5$, so that

$$ {}_4L_1=2(l_1+l_5) $$

and

$$ {}_5L_a=2.5(l_a+l_{a+5}),\ a\geqslant 5. $$

It then follows that

$$ T_a=\sum_{i=a}^{\omega} {}_n L_i $$

and

$$ e_a=T_a/l_a $$

In this handout we have considered only a very simple link to observed data, through the values P_a in the diagram at the beginning of the handout. Another more common link to the data is

$${}_nq_a=\frac{n\,{}_nM_a}{1+(n-{}_n\hat{a}_a)\,{}_nM_a}$$

Also

$$ L_{85+}=\frac{l_{85}}{M_{85+}} $$

These links are explained in a subsequent handout on stationary populations.

The value of ${}_n\hat{a}_a$ for a given age group can be calculated from retrospective maternity histories, which give, besides births, the ages at death of all children who die before some specified age (e.g., 60 months in the World Fertility Survey). Suppose one has a survey taken in 1975. One simply considers the cohort of births that is of interest (e.g., all births during 1960—64, if one is interested in constructing a period life table for 1960—64), selected from among this cohort the deaths that occurred in a given age group (say 0–11 months), and calculates $n\hat{a}_a$ (in this case ${}_1\hat{a}_0$, or simply $\hat{a}_0$) as mean age at death in the interval minus age at the start of the interval. Typically the birth histories will have age coded to the nearest age in completed months. Thus a child coded as having died at 7 months would be assigned an age at death of 7.5 (an average value) in the above calculations. After the value of ${}_n\hat{a}_a$ is estimated in this way, it is divided by 12 in order to convert it into units of years.

28880

Display 1: APL entry of age-specific death rates, and computation of life table by means of program LIFE

```
M←106273 29571 3732 2171 3338 5094 4775 4837 5685 7265 9884 13022 19164
M←M, 27373 43687 68992 109444 172754 306961
M←1E 6×M
   M
0.106273 0.029571 0.003732 0.002171 0.003338 0.005094 0.004775 0·004837 0.005685 0.007265 0.009884
 0.013022 0.019164 0.027373 0.043687 0.068992 0.109444 0 172754 0.306961
```

A *NETHERLANDS LIFE TABLE FOR MALES* 1903—1907

LIFE

AGE	*M*	*A*	*Q*	*P*	*L*	*D*	*LL*	*T*	*E*
0	.106273	.3	.098915	.901085	100000	9891	93076	5117363	51.174
1	.029571	2.0	.111679	.888321	90109	10063	340308	5024287	55.758
5	.003732	2.5	.018488	.981512	80045	1480	396527	4683979	58.517
10	.002171	2.5	.010796	.989204	78565	848	390707	4287452	54.572
15	.003338	2.5	.016552	.983448	77717	1286	385370	3896746	50.140
20	.005094	2.5	.025150	.974850	76431	1922	377349	3511375	45.942
25	.004775	2.5	.023593	.976407	74509	1758	368149	3134027	42.063
30	.004837	2.5	.023896	.976104	72751	1738	359408	2765878	38.019
35	.005685	2.5	.028027	.971973	71012	1990	350086	2406470	33.888
40	.007265	2.5	.035677	.964323	69022	2463	338954	2056385	29.793

45	009884	2.5	.048228	.951772	66560	3210	324773	1717431	25.803
50	013022	2.5	.063057	936943	63349	3995	306761	1392658	21.984
55	.019164	2.5	.091439	.908561	59355	5427	283206	1085897	18.295
60	.027373	2.5	.128099	.871901	53928	6908	252367	802691	14.885
65	.043687	2.5	.196927	.803073	47019	9259	211949	550324	11.704
70	.068992	2.5	.294214	.705786	37760	11110	161026	338375	8.961
75	.109444	2.5	.429661	.570339	26651	11451	104626	177349	6.655
80	.172754	2.5	.603240	.396760	15200	9169	53076	72723	4.784
85	.306961	—	1.000000	.000000	6031	6031	19646	19646	3.258

Note: See next page for listing of program LIFE.

Display 2: Program LIFE

```
      ∇ LIFE [□] ∇
    ∇ LIFE
(1)  A INPUT TO LIFE IS M, A VECTOR OF 19 AGE-SPECIFIC DEATH RATES. BEFORE
(2)  A THE PROGRAM IS CALLED, VALUES OF M MUST BE ENTERED INTO THE WORKSPACE AS
(3)  A       M←VECTOR OF VALUES
(4)  Q←P←L←D←LL←T←E←1900
(5)  L(1)←100000
(6)  N←(14),17ρ5
(7)  A ←(0.3 2),17ρ2.5
(8)  Q←N×M÷1+(N−A)×M
(9)  Q[19]←1
(10) P←1←Q
(11) I←1
(12) LOOP 1:L[I+1]←L[I]←L[I]×Q[I]
(13) D[I]←L[I]×Q[I]
(14) LL[I]←(N[I]×L[I+1])+A[I]×D[I]
(15) I←I+1
(16) →(I<19)/LOOP1
```

```
(17)  D[19]←L[19]
(18)  LL[19]←L[19]÷M[19]
(19)  T[19]←LL[19
(20)  I←1
(21)  LOOP 2:T[19−I]←T[20−I]+LL[19−I]
(22)  →(19>I←I+1)/LOOP 2
(23)  E←T÷L
(24)  AGE←(0 1),.5×⍳17
(25)  TABLE←⍉10  19  ⍴(AGE, M, A, Q, P, L, D, LL, T, E)
(26)     AGE          M          A          Q          P          L          D          LL         T          E'
(27)  (5  0  10  6  5  1, (4⍴  10  6), (8⍴  10  0),  10  3)▽TABLE
      ▽
```

4. MODEL LIFE TABLES

Mortality data are often incomplete or of poor quality. Because of age misreporting, the age pattern of mortality may be distorted. Demographers often find themselves in situations where they have a fairly good idea of the level of mortality (e.g., we may be able to get a pretty good idea of the level of child mortality using Brass's method), but not of the complete age pattern of mortality (by age pattern is meant a complete set of age-specific death rates or probabilities of dying).

In this situation demographers often use model life tables. In this workshop we consider two sets of model life tables: (1) a set developed by the United Nations; and (2) a set developed by Coale and Demeny.

The United Nations set includes five models: (1) Latin American, (2) Chilean, (3) South Asian, (4) Far East Asian, and (5) UN General.

The Coale-Demeny set includes four models: (1) West, (2) North, (3) East, and (4) South.

Each model, representing a distinctive age pattern of mortality, consists of a set of life tables, with one life table for each level of mortality. Usually "level of mortality" is indexed by level of life expectancy at birth.

Suppose we wish to look at the set of life tables that constitute the UN South Asian model. This model could be presented in the form of a set of life tables, with one life table for each single year of life expectancy between 20 and 80. If we wanted more detail, we could present twice as many life tables by specifying them for every half-year of life expectancy. Alternatively, we could order the life tables within the set by increments of, say, $5q_{10}$. In fact, any life table parameter can be used to order the life tables within a particular model.

A model such as the UN South Asian model is also called a "family" of model life tables. Demographers often speak, for example, of the "UN Latin American family" or the "Coale-Demeny Model West" family.

A particular model or family can be broken down by sex. At any particular mortality level within, say, the South Asian family, we actually have three life tables: male, female, and total.

Each model or family corresponds to a distinctive age pattern of mortality. For example, at a given level of life expectancy, say 50, the Coale-Demeny Model South life table shows somewhat higher child mortality and somewhat lower adult mortality than a Coale-Demeny Model West life table with the same life expectancy. (India conforms more closely to Model South than to Model West.)

How are the model life tables calculated? Where do they come from?

The procedure for constructing a set of model life tables, such as the UN set or the Coale-Demeny set, is roughly as follows: (1) First collect a base set of empirically derived life tables from all over the world, (2) Examine the life tables for accuracy, and retain only those life tables that are reasonably accurate, (3) Examine the age patterns of mortality in these life tables, (The simplest way to do this might be simply to look at graphs of the q_x function. In fact more sophisticated methods are used.), (4) Group the life tables according to type of age pattern of mortality, (5) Give each group a name (e.g., UN South Asian), (6) For each group, calculate an "average" or "typical" life table for each mortality level (e.g., each level of life expectancy).

In the end, a set of mathematical equations is developed to generate the set of "typical" life tables in each model life table family. Usually these are regression equations.

Computer packages like MORTPAK do not actually store the model life tables in the computer. They store the equations that generate the model life tables. For example, if the user wants a Coale-Demeny Model West life table for females with a life expectancy of 50, the program generates this model life table from the equations.

We won't worry about how the model life tables are generated. We will focus on how to use them.

Model life tables are also published in book form, arranged by level of life expectancy. Attached is a sample page from the published UN model life tables. The page refers to the UN South Asian family. Two male model life tables are presented, one with life expectancy 35 and one with life expectancy 36.

United Nations Model Life Tables—Males

South Asian Pattern

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	·26744	·22680	100000	22680	84804	3499992	35.000	0.330
1	.05842	.20238	77320	15648	267844	3415187	44.169	1.352
5	.00970	.04734	61672	2919	301061	3147343	51.034	2.500
10	.00384	.01901	58753	1117	290970	2846282	48.445	2.500
15	.00435	.02154	57635	1242	285135	2555312	44.336	2.550
20	.00510	.02520	56394	1421	278500	2270177	40.256	2.560
25	.00610	.03005	54973	1652	270848	1991677	36.230	2.570
30	.00757	.03718	53321	1982	261809	1720829	32.273	2.582
35	.00974	.04758	51338	2443	250813	1459019	28.420	2.593
40	.01305	.06325	48896	3093	237046	1208207	24.710	2.597
45	.01765	.08465	45803	3877	219700	971160	21.203	2.597
50	.02482	.11706	41926	4908	197762	751461	17.923	2.582
55	.03350	.15488	37018	5733	171157	553698	14.957	2.570
60	.04847	.21659	31285	6776	139812	382542	12.228	2.548
65	.06861	.29286	24509	7178	104615	242730	9.904	2.502
70	.09727	.38910	17331	6744	69326	138115	7.969	2.430
75	.12983	.48246	10587	5108	39345	68789	6.497	2.339
80	.16452	.56743	5479	3109	18899	29444	5.374	2.267
85	.22477	—	2370	2370	10545	10545	4.449	4.449

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.25865	.22045	100000	22045	85230	3600000	36.000	0.330
1	.05549	.19354	77955	15087	271869	3514770	45.087	1.352
5	.00922	.04506	62868	2833	307257	3242901	51.583	2.500
10	.00366	.01815	60035	1090	297450	2935644	48.899	2.500
15	.00417	.02062	58945	1216	291748	2638194	44.757	2.551
20	.00488	.02413	57729	1393	285248	2346446	40.646	2.560
25	.00585	.02882	56336	1624	277736	2061198	36.587	2.570
30	.00726	.03566	54713	1951	268848	1783462	32.597	2.583
35	.00936	.04579	52762	2416	258000	1514614	28.707	2.595
40	.01259	.06112	50346	3077	244342	1256615	24.960	2.599
45	.01711	.08219	47269	3885	227020	1012272	21.415	2.600
50	.02418	.11425	43384	4957	204948	785252	18.100	2.585
55	.03279	.15184	38427	5835	177972	580304	15.101	2.573
60	.04760	.21315	32592	6947	145950	402331	12.344	2.551
65	.06753	.28896	25645	7410	109739	256382	9.997	2.505
70	.09593	.38491	18235	7019	73163	146643	8.042	2.434
75	.12831	.47844	11216	5366	41823	73480	6.551	2.343
80	.16299	.56406	5850	3300	20244	31657	5.412	2.271
85	.22344	—	2550	2550	11413	11413	4.475	4.475

5. Own Child Method

Basic logic of the own-children method

$$F_{24}^{(1977)} = \frac{B_{24}}{W_{24}}$$

1977		1980 Census
B_{24}	Reverse survival	C_{27}^{3}
W_{24}	Reverse survival	W_{27}

Adjustments are made for children not matched to mothers (not matched=non-own); the adjustment factor is the ratio of all children to own children of each given age of child. Children up to age 14 are reverse-survived, yielding a 15 year fertility trend. The method requires census populations of children aged 0-14 and women aged 15-64.

Own - Children Method
Basic Formulae

Continuous Formulation

a : Woman's age

x : Child's age

$f_a(t)$: Instantaneous age-specific birth rate for women aged a at time t.

$C_{x,a}$: Number of own children aged x of mothers aged a enumerated in census.

$B_a(t)$: Number of births to women aged a at time t.

$W_a(t)$: Number of women aged a at time t.

ℓ_y : Probability of surviving from birth to age y.

$$B_{a-x}(t-x) = C_{x,a}\ (\ell_0/\ell_x)$$

$$W_{a-x}(t-x) = W_a(t)\ (\ell^f_{a-x}/\ell^f_a)$$

$$f_{a-x}(t-x) = \frac{B_{a-x}(t-x)}{W_{a-x}(t-x)}$$

$C_{x,a}$ is viewed as already adjusted for misenumeration and non-own children.

Basic logic (continued)

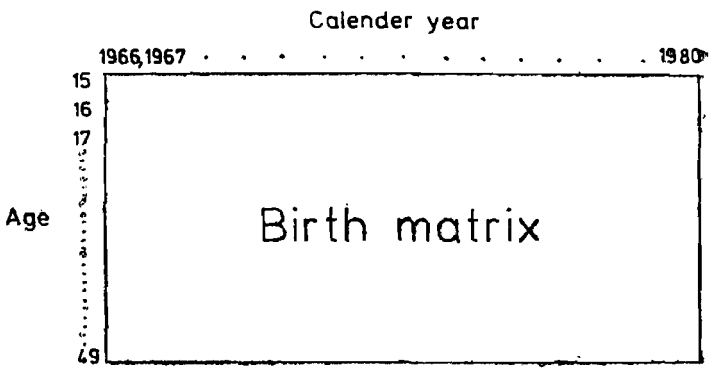


Figure 1

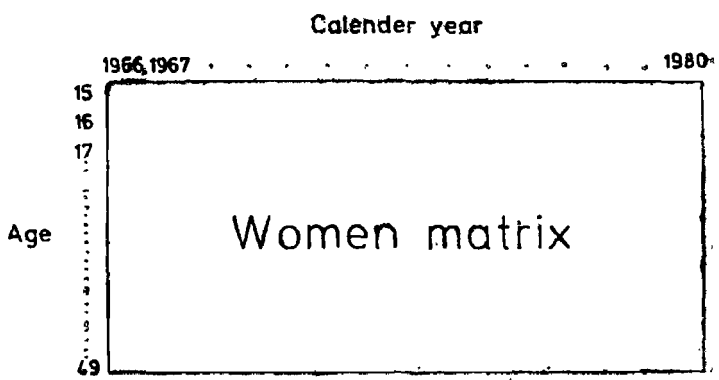


Figure 2

Divide the first matrix by the second, term by term, to get the age specific birth rate matrix.

Lexis Diagram Portrayal of Reverse-Survival (discrete formulation)

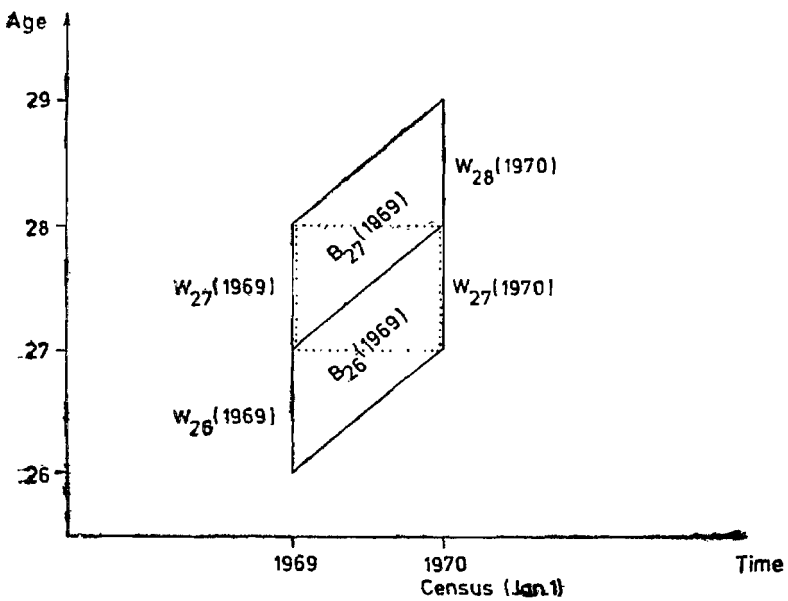


Figure 3

Central rate for the square

$$F_{27}(1969) = \frac{1/2\,[B_{26}(1969) + B_{27}(1969)]}{1/2\,[W_{27}(1969) + W_{27}(1970)]}$$

$$= \frac{B_{26}(1969) + B_{27}(1969)}{W_{27}(1969) + W_{27}(1970)}$$

Discrete Formulation (continued)

$$B_{26}\ (1969) = C_{0,27}\ U^{c}_{0,27}\ V_0\ \frac{l_0}{L_0}$$

$$B_{27}\ (1969) = C_{0,28}\ U^{c}_{0,28}\ V_0\ \frac{l_0}{L_0}$$

$$W_{26}\ (1969) = W_{27}\ (1970)\ U^{w}_{27}\ \frac{L^{f}_{26}}{L^{f}_{27}}$$

$$W_{27}\ (1969) = W_{28}\ (1970)\ U^{w}_{28}\ \frac{L^{f}_{27}}{L^{f}_{28}}$$

The factors U^c and U^w are adjustment factors for underenumeration and misenumeration.

The factor V_x is an adjustment factor for non-own children, calculated as the reciprocal of the proportion of children aged x to x+1 at the time of the census who are matched to mothers.

6. FERTILITY ESTIMATION USING CHILDREN EVER BORN DATA

I. P/F Ratio Method Based on Data About All Children

Data Required:

(1) Age-Specific Birth Rates (ASBRs) by 5-year age groups of women for the year previous to a census or survey.

(2) Average number of children ever born (i.e., average parity) per woman by 5-year age groups of women from the census or survey.

Assumptions:

(1) Percentage error in reported ASBRs is the same at all ages.

(2) In the census or survey, women in one (or more) age groups (usually below ages 30 or 35) report children ever born quite accurately and the number of women in these age groups is reported quite accurately.

(3) Fertility for the age group(s) in question and all lower ages has remained relatively constant for the past a-15 years where a is the upper age of the age group(s) in question (actually fertility must only have remained constant by age within the boundaries of the triangle in the Lexis Diagram of Figure 1.) That is, fertility has remained relatively constant for the past 5, 10, 15 or 20 years for women ages 15—19, 15—24, 15—29, or 15—34 if the upper age of the age group(s) in question is 19, 24, 29 or 34, respectively.

(4) Distribution of numbers of children ever born for deceased and migrant women is similar to that for all women.

Objective:

To correct the reported ASBRs for all ages by the common multiplicative adjustment factor P/F where:

(i) P is the average parity for an age group of women, i.e., P is the average number of children ever born per woman of this age group calculated as the total number of children ever born to the women in this age group divided by the total number of women in this age group, (ii) F is the cumulative

P/F Ratio Method
Illustrated for age group 30-34

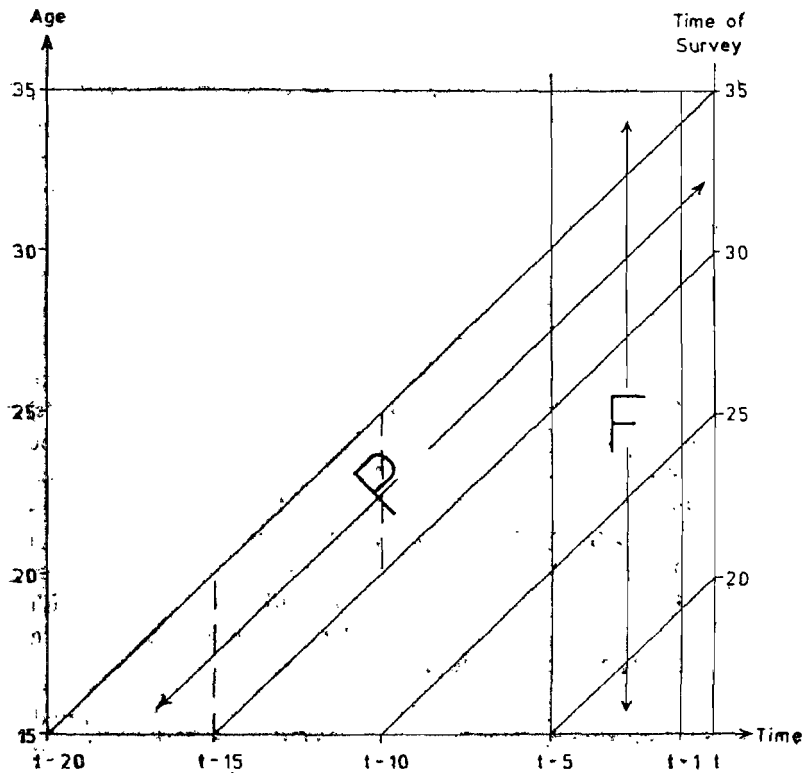


Figure 1

fertility up to the end of the age group, calculated as the sum of the ASBRs to the end of the age group multiplied by 5. (Often the multiplicative adjustment factor is taken to be the average of the P/F ratios for two or more age groups if the above assumptions seem to be equally plausible for those age groups).

Note: Because P and F are not strictly comparable (see Lexis Diagram of Figure 1), even under constant fertility, F must be adjusted slightly, as described in United Nations (1983), before multiplying the ASBRs by P/F. This is done by the microcomputer program.

Comments:

(1) With regard to Assumption (1), the ASBRs are generally calculated from (i) the census or survey data on births during the last year, which generally suffer from errors in reported time of birth and possibly other errors, or from (ii) registered births, which generally suffer from under-registration.

(2) With regard to Assumption (2), average parity P tends to be progressively under-reported with increasing age, especially at the older reproductive ages (say, above age 35). However, if such under-reported does not occur for the age group(s) on which the P/F ratio is based, then the P/F Ratio Method is not affected. Such Progressive under-reporting may often be identified by average parities P that fail to increase rapidly enough, or even decrease, as age increases. Although this same pattern for average parities is obtained if fertility has been rising, the under-reporting of average parity with increasing age is a more likely explanation because rising fertility is not common.

(3) With regard to Assumption (3), if there has been rapid fertility decline recently, one should base the P/F ratio on the youngest age group possible (generally 20—24 since there are often difficulties with 15—19), both because this assumes constant fertility for a shorter period of time and because the decline may be greatest at the oldest ages. In fact, if the fertility decline affects mainly women in the older age groups (e.g., if contraceptives are generally used only after desired family size has been attained), then the P/F ratio may be based on any of the younger age groups, or on some composite of them.

(4) If all assumptions hold, ideally the P/F ratios for the different ages groups should be similar. In practice, however, this is often not the case. If the P/F ratios for the 20—24 and 25—29 age groups are similar, then either one can be used. Otherwise, a weighted average (weighted by the relative proportions of women in the 20—24 and 25—29 age groups) or unweighted average of the two is often used. However, if there is good reason to believe Assumptions (2) and (3) are better satisfied for other age group(s), then the P/F ratio should be based on those age group(s).

(5) If fertility at all ages has been declining in the past, then the P/F ratios will increase with age (although this effect may be counteracted by progressive under-reporting of average parity P with increasing age, as mentioned above); and if fertility at all ages has been rising in the past, then the P/F ratios will decline with age. Thus, with highly reliable data, the P/F ratios may be used to identify declining or rising fertility.

(6) A general background on children ever born data and on the methods described in this handout is given on pp. 27—32 of United Nations (1983).

Note: There are two slightly different variants of the P/F Ratio Method depending on whether the ASBRs for the year preceding the census or survey are calculated from (i) vital registration data (registered births) with births tabulated by age of mother at delivery, or (ii) census or survey data with births tabulated by age of mother at the end of the period. The adjustment of F to make it comparable to P is slightly different in the two cases; and the ASBRs calculated by (ii) pertain to unconventional age groups bordered by exact ages 14.5, 19.5, 24.5 ...., 49.5 so must be adjusted in order to pertain to the conventional 5-year age groups. These adjustments are described in United Nations (1983) and are carried out by the microcomputer

program. Hence the investigator must simply specify which way the ASBRs are calculated when executing the microcomputer program.

Computational Procedure and Example: These are given in detail on pp. 33—37 of United Nations (1983).

Software for microcomputer:

P/F Ratio Method from EASWESPOP

Description: Uniform (constant multiple) adjustment of observed age-specific fertility rates to agree with level of fertility indicated by average parity.

Input data needed:

(i) Number of children ever born (or average parity per woman) by 5-year age groups of women ages 10—49.

(ii) Number of children born during the year preceding the census or survey by 5-year age groups of women ages 10—49; or number of registered births in the year of the census or survey by 5-year age groups of women ages 10—49 and mid-year female populations of such age groups.

(iii) Total number of women in each such 5-year age group (irrespective of marital status).

(iv) Total population if the crude birth rate is to be estimated.

(Note: For the input data, age group 10—14 is optional and zero should be entered if information is not available).

References:

(a) East-West Centre, 1987. *EASWESPOP: Microcomputer Software developed by the East-West Population Institute. Fertility Estimate Programs.* Honolulu: East-West Center.

(b) United Nations, 1983. *Manual X: Indirect Techniques for Demographic Estimation* (Population Studies, No. 81), Chap. II. B.2, pp. 32—37. New York : United Nations.

II. P_1/F_1 Ratio Method Based on First Births

The P_1/F_1 Ratio Method, including its data requirements, assumptions and objective, is the same as the P/F Ratio Method except that it refers to first births only.

Thus in place of ASBRs we work with age-specific first birth rates (ASFBRs) in calculating F_1, and in calculating P_1 we are only interested in the number of women who have borne at least one child rather than the specific number of children ever born to each woman. Because the former is often reported more accurately than the latter, and because first-birth fertility is more likely to have been constant in the past than overall fertility the P_1/F_1 Ratio Method has some advantages over the P/F Ratio Method.

However, a significant disadvantage is that, strictly speaking, P_1/F_1 should only be used as a multiplicative adjustment factor for ASFBRs rather than ASBRs although it may be used for the latter under some added assumptions; see pp. 37-38 of United Nations (1983).

Computational Procedure and Example: These are given in detail on pp. 38—41 of United Nations (1983).

Note: We have no microcomputer software for this method, but it may be executed quite easily with a hand calculator.

Reference: United Nations, 1983. *Manual X: Indirect Techniques for Demographic Estimation* (Population Studies, No. 81), Chap. II. B. 3, pp. 37—41. New York: United Nations.

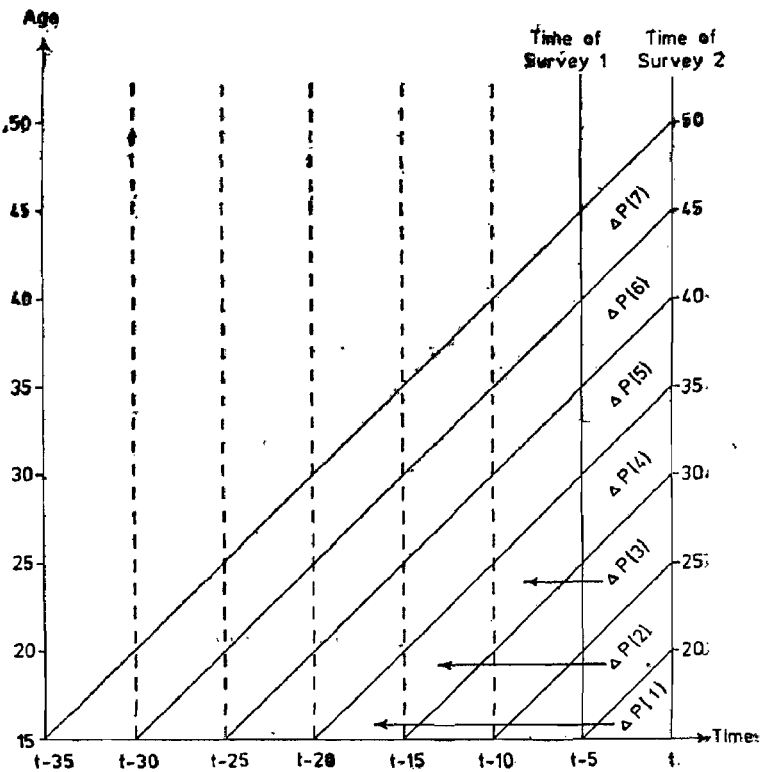
III. A P/F Ratio Method for Changing Fertility:
Comparison of period Fertility Rates with Average Parities for a Hypothetical Intersurvey or Intercensal Cohort

This method requires data on average number of children ever born (i.e., average parity) per woman by 5-year age groups of women for two surveys or censuses 5 or 10 years apart as well as a set of ASBRs for the intersurvey or intercensal period.

One then Computes the average parity increments (differences) for different cohorts for the period between the surveys or censuses and cumulates them to obtain average parities for a hypothetical

cohort experiencing these observed average parity increments for the intersurvey or intercensal period (see Lexis Diagrams of Figures 2 and 3).

Comparison of Period Fertility Rates with Average Parities for a Hypothetical Cohort
5-year intersurvey interval



$\Delta P(1) = P(1,2)$

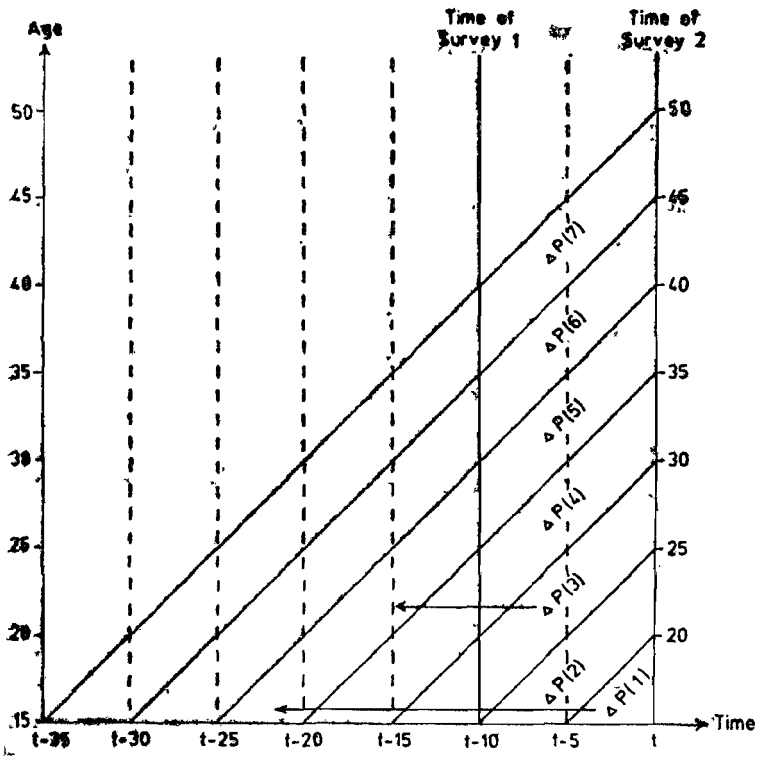
$\Delta P(i+1) = (i+1,2) - P(i,1), i = 1, \ldots, 6;$

$P(i,5) = \sum_{j=1}^{i} \Delta P(j)$

E.g., for ages 30-34 at Survey 2,
$P(4,5) = \Delta P(1) + \Delta P(2) + \Delta P(3) + \Delta P(4)$,
as illustrated above.

Figure 2

Comparison of Period Fertility Rates with Average Parities for a Hypothetical Cohort
10-year intersurvey interval



$\Delta P(1) = P(1,2)$

$\Delta P(2) = P(2,2)$

$\Delta P(i+2) = P(i+2,2) - P(i,1)$ $i = 1, \ldots, 5$

Then, e.g., for ages 30-34 at Survey 2, $P(4,5) = \Delta P(2) + \Delta P(4)$; and for ages 35-39 at Survey 2, $P(5,5) = \Delta P(1) + \Delta P(3) + \Delta P(5)$, as illustrated above

Figure 3

The rest of the method is essentially the same as the basic P/F Ratio Method for all children (I. above) except that F must be based on the entire intersurvey period because fertility is changing

(e.g., F may be based on the average of the age-specific fertility rates at the beginning and end of the intersurvey or intercensal period).

Computational Procedure and Example: These are given in detail on pp. 41—45 of United Nations (1983).

Note: We have no microcomputer software for this method, but it may be executed quite easily with a hand calculator.

Reference: United Nations, 1983. *Manual X: Indirect Techniques for Demographic Estimation*, (Population Studies, No. 81), Chap. II. B. 4, pp. 41—45. New York: United Nations.

IV. Parity Increment Method: Estimation of Age-Specific Birth rates from the Increment (Difference) in Cohort Parities between Two Surveys or Censuses

Data Required: Average number of children ever born (i.e. average parity) per woman by 5-year age groups of women from two censuses or surveys approximately 5 or 10 years apart.

Assumptions:

(1) Women in all age groups for ages 15—49 report children ever born quite accurately for two surveys or censuses approximately 5 or 10 years apart, and the number of women in these age groups is reported quite accurately in both surveys orcensuses.

(2) Distribution of numbers of children ever born for deceased and migrant women is similar to that for all women.

Objective: To estimate a schedule of age-specific birth rates (ASBRs) for the intercensal or intersurvey period by 5-year age groups of women, based on average parities for hypothetical cohort experiencing the observed intersurvey or intercensal average parity increments (differences).

Comments: The Parity Increment Method is useful when fertility is changing, and it resembles the P/F Ratio Method for Changing Fertility (III. above). However, the Parity Increment Method

has the advantage of not requiring a schedule of age-specific fertility rates for the intercensal or intersurvey period as input data. Instead of adjusting such a schedule by a common constant (the P/F ratio as in the P/F Ratio Method for Changing Fertility, the Parity Increment Method estimates such a schedule of age-specific fertility rates for the intercensal or intersurvey period from scratch, based on the average parities P for a hypothetical cohort experiencing the observed average parity increments (differences) for the intersurvey or intercensal period.

More specifically, the average parity increments for different cohorts for the period between the surveys or censuses are cumulated exactly as in the P/F Ratio Method for Changing Fertility, to obtain average parities P for this hypothetical cohort. From this, a schedule of age-specific fertility rates is derived by equations describing the relationship between average parity P for an age group and cumulative fertility F to the upper age of that age group.

Thus, just as with the P/F Ratio methods, the Parity Increment Method relates average parity P to cumulative fertility F. However, with the P/F Ratio methods we adjust F to be comparable with P (in order to find the P/F ratio) whereas with the Parity Increment Method we adjust P in order to *estimate* F at each age. The process is described in United Nations (1983) and is carried but by the microcomputer program.

As mentioned before, the Parity Increment Method has the advantage over the P/F Ratio Method for Changing Fertility of not requiring a schedule of ASBRs as input data. However, it has the disadvantage of requiring accurate reporting of children ever born for all age groups of women rather than just for the age group(s) on which the P/F ratio is based. This can be a significant disadvantage because, as mentioned earlier, older women often tend to forget some of their children and hence under-report number of children ever born.

Computational Procedure and Examples: These are given in detail on pp. 59-64 of United Nations (1983).

Software for microcomputer :

Parity Increment Method **from** EASWESPOP.

Description: Estimation of Intercensal age-specific fertility rates using parity distributions in two censuses which are 5 or 10 years apart.

Input data needed :

(i) Number of children ever born by 5-year age groups of women ages 15—49 for two points in time approximately 5 or 10 years apart.

(ii) Number of women by the same 5-year age groups for the same two points in time.

(iii) Total population if the crude birth rate is to be estimated.

Reference :

(a) East-West Center, 1987. *EASWESPOP: Microcomputer Software developed by the East-West Population Institute. Fertility Estimate Programs.* Honolulu : East-West Center.

(b) United Nations, 1983. *Manual X: Indirect Techniques for Demographic Estimation* (Population Studies, No. 81) Chap. II, C, pp. 58—64. New York: United Nations.

7. CHILD MORTALITY ESTIMATION USING CHILDREN EVER BORN AND CHILDREN SURVIVING DATA

I. Estimation of Child Mortality Rates Using Data Classified by Age of Woman.

Data Required :

(1) Average number of children ever born (i.e., average parity) per woman by 5-year age groups of women.

(2) Average number of children still living (surviving) per woman by 5-year age groups of women.

Objective:

To estimate q(x), the probability of dying between birth and exact age x, and the period to which it refers, for ages

x=1, 2, 3, 5, 10, 15, 20.

The basic idea is to relate D (i), the proportion dead among children ever born to women in the ith 5-year age group (i=1 signifies 15—19 age group, i=2 signifies 20—24, etc.), to q (x), the probability of dying between birth and exact age x, for appropriate x.

Brass discovered that for a wide range of mortality experience q(x)/D (i) is approximately constant for each of the following pairs of corresponding x and i values:

Women's age

group i :	1(15—19)	2(20—24)	3(25—29)	4(30—34)	5(35—39)
Age x :	1	2	3	5	10
				6(40—44)	7(45—49)
				15	20

i.e., q(x)=k (i) D (i) where k(i) is a constant dependent only on woman's age group and not on the level of mortality. This relationship makes sense in that presumably the x value is related, generally speaking, to the average age of children of women in the corresponding age group i.

Brass's original method for calculating the multipliers assumed:

(1) The risk of dying of a child is a function only of the age of the child and not of other factors such as mother's age or duration of marriage, or child's birth order.

(2) Fertility and childhood mortality have remained constant in the recent past.

(3) Mortality for children with deceased and migrant mothers is similar to that for all children.

The variant of Brass's method that we use, due to Trussell, derives the estimate of q(x) for these same x values using multipliers k (i) calculated by regression equations rather than by the method of Brass. This variant does not assume constant mortality in the recent past and gives estimates of the periods to which the q (x) values refer. The assumptions are the same as before except that a smooth change in past childhood mortality is assumed rather than constant mortality.

How do violations of these assumptions affect the results? To begin with, violation of the assumption of constant fertility usually does not seriously affect them.

However, other violations of assumptions have more impact. First of all, the estimate of q (1) based on data from women aged 15—19 is usually unreliable, both because of higher mortality for children of such women and because of the small numbers of children ever born and dead for this age group. Moreover, since mortality of children is to some extent positively correlated with mortality of mothers, child mortality estimates based on the past experience of surviving mothers are biased somewhat downward.

The most serious problem involves underreporting of dead children relative to surviving children which for any age group of women will, of course, seriously affect the corresponding q(x) estimate. Since such differential underreporting of dead children relative to surviving children is usually greater above age 35 or 40, the estimates of q (2), q (3), q(5), and sometimes q (10) are considered the most reliable.

In any case, as a partial check of the data, it is a good idea to graph average reported parity by 5-year age groups of women. Unless fertility rose at some time in the past, average parities should increase with age up to age group 45—49.

The computational procedure and a detailed example are given on pp. 77-81 of United Nations (1983).

II. Estimation of Child Mortality Rates Using Data Classified by Duration of Marriage.

Data Required:

(1) Average number of children ever born (i.e., average parity) per woman by 5-year duration-of-marriage group of ever-married women.

(2) Average number of children still living (surviving) per woman by 5-year duration-of-marriage group of ever-married women.

Objective:

To estimate q(x) the probability of dying between birth and exact age x, and the period to which it refers, for ages

x=2, 3, 5, 10, 15, 20, 25.

Similar to before, D(i), now denoting the proportion dead among children ever born to women in the ith duration of marriage group (i=1 signifies 0—4 years, i=2 signifies 5—9, etc.), is related to q (x), the probability of dying between birth and exact age x, for appropriate x.

(*Note:* Duration of marriage is defined as the time elapsed since entry into *first* union, regardless of whether this union is legal. The procedure to be described is preferred only when duration of marriage, as just defined, is more accurately reported than age of woman.)

More precisely, for a wide range of mortality experience q (x)/D (i) is approximately constant for each of the following pairs of corresponding x and i values:

Duration of marriage group i :	1(0-4)	2(5-9)	3(10-14)	4(15-19)	5(20-24)	6(25-29)	7(30-34)
Age x :	2	3	5	10	15	20	25

i.e., q (x)=k (i) D (i) where k (i) is a constant dependent only on duration of marriage and not on the level of mortality.

(Note that age x=1 is not included in the x values this time.) Again, this relationship makes sense in that presumably the x value is related, generally speaking, to the average age of children of women in the corresponding marriage duration group i.

Similar to before, the constants k (i) are calculated from regression equations and estimates of the periods to which the q (x) values refer are included in the procedure.

The assumptions are the same as for the preceding procedure that uses age of woman. Likewise, the problems that arise from violations of these assumptions are similar to those for the preceding procedure. Of course, there is no direct estimate of q (1) with the present procedure, and the most serious problem arises from differential underreporting of dead children relative to surviving ones for women's duration of marriage groups, rather than for women's age groups.

The computational procedure and a detailed example are given on pp. 81—85 of United Nations (1983).

Software for microcomputer:

CEBCS from MORTPAK

Description: Estimation of child mortality rates from data on average number of children ever born and average number of children surviving, tabulated either by age group of mother or by duration of her marriage (rates calculated separately based on each of Coale-Demeny and United Nations developing countries moodel life tables).

Input data needed:

(i) Average number of children ever born per woman by 5-year age groups of women ages 15—49; or by 5-year duration-of-marriage groups 0—4, 5—9...., 30—34 of ever-married women.

(ii) Average number of children surviving per woman by the same 5-year age groups of women; or by the same 5-year duration-of-marriage groups of ever-married women.

(iii) Mean age of mother at childbearing in the population(only needed if data is tabulated by age group and used only for rates based on United Nations developing countries models). This may be calculated as

$$\sum_{a=3}^{9} (5a+2\cdot5)5a+5\,{}^{B}5a \qquad \sum_{a=3}^{9} 5a+5\,{}^{B}5a \text{ where } 5a+5B5a$$

is the number of births to women between exact ages 5a and 5a+5, a=3, .,9

References:

(a) United Nations, 1988. *Mortpak-Lite: The United Nations Software Package for Mortality Measurement. Interactive Software for the IBM-PC and Compatibles* (Population Studies, No. 104), esp. pp. 47—51. New York: United Nations.

(b) United Nations, 1983. *Manual X : Indirect Techniques for Demographic Estimation* (Population Studies, No. 81), Chap. III. A,B,C, pp. 73—85. New York: United Nations.

(c) Palloni, A. and L. Heligman, 1985. "Re-estimation of structural parameters to obtain estimates of mortality in developing countries". *Population Bulletin of the United Nations*, No. 18, pp. 10—33. New York: United Nations.

8. POPULATION PROJECTION BY THE COHORT-COMPONENT METHOD (INCLUDING MIGRATION)

Data Required:

(1) Initial population at some point in time by sex and by 5-year age groups.

(2) Survival rates by sex and by 5-year age cohort for each of the seven 5-year periods 0—5, 5—10, ..., 30—35 years after the time of the initial population.

(3) Age-specific fertility rates by 5-year age groups of women ages 15—49 for each of the seven 5-year periods.

(4) Age-specific net immigration (in-migration) by sex and by the same age groups as for the initial population, for each of the seven 5-year periods.

Objective:

To project the initial population by sex forward 35 years by 5-year time periods.

We describe a simple one-sex projection of the population in 5-year age groups out to ages 80+, projected over a 5-year time period. This projection, of course, may be successively repeated over any number of 5-year time periods.

Our notation will follow that of Appendix One of the manual referenced below (on last page). To begin with, we number the cohorts as follows:

Cohort index (c)	Age at Beginning	Age at End
0	To be born	0—4
1	0—4	5—9
2	5—9	10—14
3	10—14	15—19
4	15—19	20—24
5	20—24	25—29
6	25—29	30—34
7	30—34	35—39
8	35—39	40—44
9	40—44	45—49
10	45—49	50—54
11	50—54	55—59
12	55—59	60—64
13	60—64	65—69
14	65—69	70—74
15	70—74	75—79
16	75+	80+

At the end of each projection cycle, the estimated population for cohorts 15 and 16 is combined to give the estimated population for age group 75+. Thus the 5-year projection cycle always ends with the same 16 age groups with which it began: 0—4, 5—9

Population Projection over a 5-Year Time Period

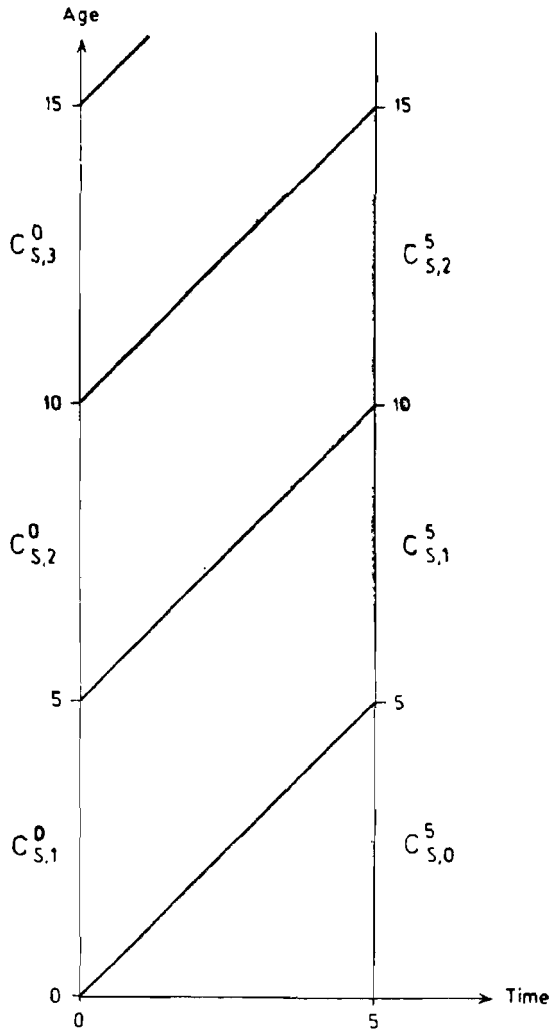


Figure 1

...,75+(If the input data does not includes this many age groups, the computer program will estimate such).

Let $C^0_{s,c}$ and $C^5_{s,c}$ be the population of cohort c of sex s at the beginning (superscript 0) and end (superscript 5), respectively, of the 5-year time period. Let $S_{s,c}$ be the survivial rate of cohort c of sex s; i.e., the proportion surviving from the beginning to the end of the 5-year period. Finally, let Ms,c be the net immigration of cohort c of sex s during the 5-year period; i.e., the number of immigrants minus number of out-migrants . (Note that $M_{s,c}$ may be positive or negative).

Then for all cohorts except the cohort c=0, the number of survivors of the beginning population C^0s,c to the end of the 5-year period is $C^0s,c \cdot Ss,c$. Moreover, if we assume migration for each cohort is distributed uniformly over age and time and that survival rates are the same for migrants as non-migrants, then migrants are exposed to the risk of death *after migration* for an average of one-half of the projection period. Thus their survival rate *from the time of migration (when they are alive) to the end of the period* is taken to be the average $(1+Ss,c)/2$ of the survival rates $S_{s,c}$ and 1 (of surviving to the end of the period) pertaining to populations at the beginning and end of the period respectively. Thus migration contributes

$M_{s,c}\left(\frac{1+S_{s,c}}{2}\right)$ to the population at the end of the 5-year period.

Consequently for all cohorts except c=0, the population at the end of the period is

$$C^5_{s,c} = C^0_{s,c} \cdot S_{s,c} + M_{s,c}\left(\frac{1+S_{s,c}}{2}\right)$$

(Note that this holds for $M_{s,c}$ negative as well as positive since we must subtract from the number $C^0_{s,c} \cdot S_{s,c}$ of survivors of the beginning population to the end of the period those out-migrants who survived from the time of migration to the end of the period).

For these cohorts c=1,2,....16, the survival rates are calculated by the following formulae from a model life table that describes the

Population Projection over a 5-Year Time Period
Either Sex, All Cohorts Exeept Birth Cohort

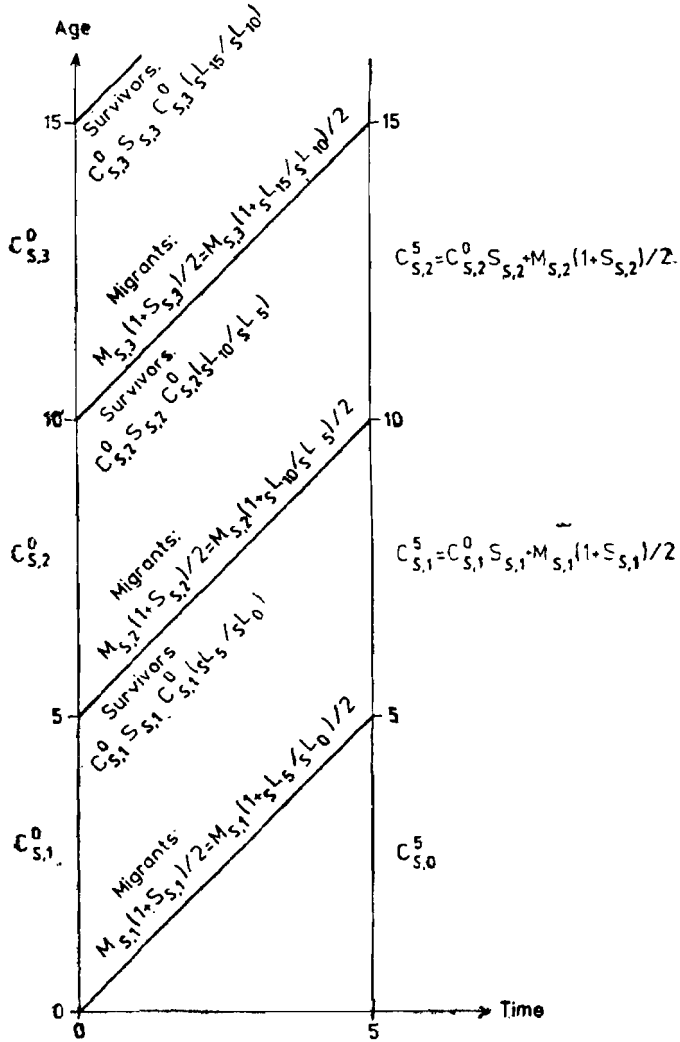


Figure 2

mortality experience of the particular sex during the 5-year period:

$S_{s,c}={}_5L_{5c}/{}_5L_{5c-5}$, c=1,2,.....,15;

$S_{s,16}=T_{80}/T_{75}$

The preceding for cohorts c=1,2,....,16, of course, applies to either females (subscript s=f) or males (subscript s=m). It remains to project by sex to the end of the period the cohort c=0 of births B that occur during the period. Let W_i^0 and W_i^5 be the number of women in age group i at the beginning and end of the 5-year period, respectively, where i=1 corresponds to ages 15—19, i=2 to ages 20—24,..., i=7 to ages 45—49. (Note that w_1^0 is given initially and $W^5{}_1$ has been calculated just above). Let F_i be the age-specific fertility (birth) rate for women in age group i, i=1,2...,7. Letting

$$\bar{W}_i=\left(W_i^0+W_i^5\right)/2 \qquad (1)$$

be the average number of women in age group i (i=1,2...,7) that are at risk of bearing children during the period, we estimate the total births of the sexes combined during the period to be

$$B=5\sum_{i=1}^{7}F_i\bar{W}_i.$$

Following the manual's notation, we let g be the proporation of births that are females. Then the numbers of female and male births during the period are gB and (1—g) B, respectively. Note that the sex ratio at birth SRB=(1—g)B/gB=(1—g)/g so that

$$g=1/(1+SRB).$$

Thus the number of females and males born during the period who survive to the end of the period are

$$gB.S_{f,0}, \qquad (3)$$

and

$$(1-g)B.S_{m,0}, \qquad (4)$$

respectively.

Here $S_{f,0}$ and $S_{m,0}$ are the female and male survival rates calculated by the following formulae from model life tables that describe the mortality experience of females and males, respectively, during the 5-year period:

$$S_{f,0}={}_5L_0^f/5.1_0^f \qquad (5)$$

$$S_{m,0}={}_5L_0^m/5.1_0^m \qquad (6)$$

For the cohort c=0, we must add to (3) and (4) the contribution of migration to the male and female populations at the end of the period in order to find $C^5_{f,0}$, and $C^5_{m,0}$, respectively. As with the other cohorts, the survival rate of migrants in cohort c=0 is taken to be a(weighted) average of the survival rates $S_{s,0}$ and 1 (of surviving to the end of the period) pertaining to populations at the beginning and end of the period, respectively. But this time these two survival rates are not weighted equally. Because the age composition of migrants below age 5 usually shows larger numbers at the higher ages where mortality is lower than for infants, we assign 1/3 weight to $S_s,0$ and 2/3 weight to 1 to obtain the weighted average

$$(2/3)1+(1/3)S_{S,0}=(2+S_{S,0})/3.$$

This will serve as our survival rate for migrants of each sex in the cohort c=0.

Thus the male and female populations in the cohort c=0 at the end of the 5-year period are

$$C^5_{f,0}= gB.S_{f,0}+M_{f,0}(2+S_{f,o})/3 \qquad (7)$$

$$C^5_{m,0}=(1-g)B.S_{m,0}+M_{m,0}(2+S_{m,0})/3 \qquad (8)$$

where $M_{f,o}$ and $M_{m,0}$ denote female and male net immigration during the 5-year period for cohort c=0; i.e., number of in-migrants minus number of out-migrants. Plugging equations (1), (2), (3), (4), (5), and (6) into equations (7) and (8), we get

$$C^5_{f,0}=\left\{g._5L^f_0/2\ (1^f_0)\right\}\sum_{i=1}F_i\left(\tfrac{1}{2}W_1^0+{}^{W^5}_{i}\right)+M_{f,0}\left\{10\ (1^f_0)+\right.$$

$$\left.5\ L^f_0\right\}/15(1^f_0),$$

$$C^5_{m,0}=\left\{(1-g)\ {}_5L^m_0/\ 5(1^m_0)\right\}\sum_{i=1}{}_i\ \left({}^{W^0}_{i}+{}^{W^5}_{i}\right)+M_{m,0}$$

$$\left\{10\ (1^m_0)+{}_5L^m_0\right\}/15\ \left(1^m_0\right)$$

Population Projection over a 5-Year Time Period
Females,
Birth Cohort

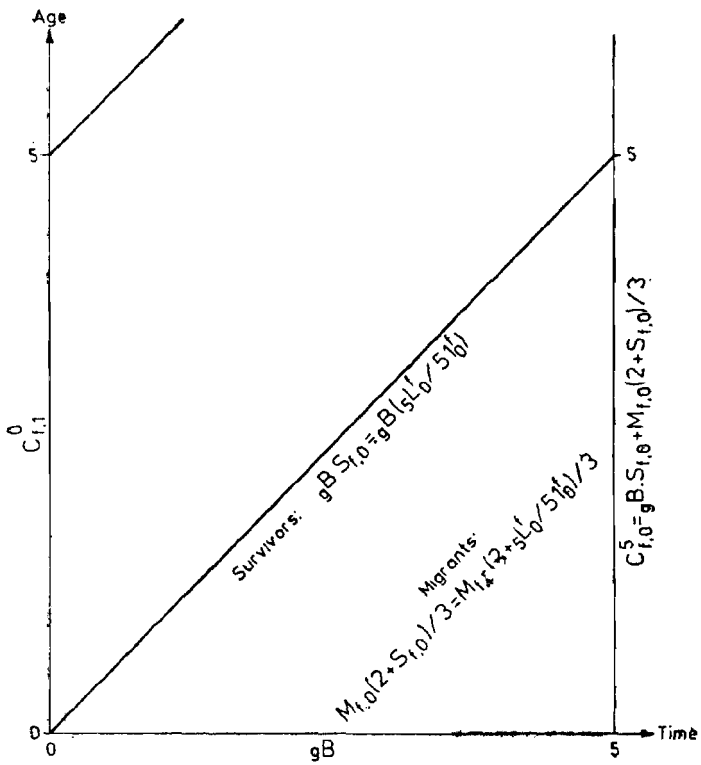


Figure 3

Note that the input migration data for our microcomputer program (see below) are in age-period from (squares of the Lexis diagram) whereas from the preceding it is clear that they are used in cohort-period from (parallelograms of the Lexis diagram). The computer program

makes the conversion from one form to the other by assuming uniform migration with respect to age and time (and, in effect all migration occuring before age 80). Thus each input age-period net immigration total corresponding to a square in the Lexis diagram is divided equally into the totals for its two component triagngles (formed by the cohort line diagonalizing the square) in order to generate cohort-period totals. (See Lexis diagram of Figure 4; also, pp. 124-125 of manual referenced below). Although, as noted earlier, it is not completely realistic to assume uniform migration with respect to age for ages 0—4, recall that we did take that into consideration in choosing the survival ratio $(2+S_8,0)/3$ above for migrants in the cohort c=0.

Examples: Some examples of population projection by the Cohort-Component Method (Including Migration) just described are given in the manual referenced below (on last page); see, e.g., Chap. 2, pp. 30-45 of the manual. An example showing more detail in the calculations follows the Note just below.

Note: Much of the manual describes the mainframe version of the procedure. The IBM/PC version that we shall use on our microcomputers is a full implementation of the mainframe version; see "1987 Supplement to Computational Methods for Population Projection", pp. 153ff. of the manual, and especially the section entitled "Fivfiv-Sinsin for IBM/PCs and Compatible Microcomputers," pp. 173—191 of the manual.

Example: Projecting Kerala Males from the 1971 Census Forward

In a forthcoming Occasional Paper of the Office of the Registrar General and Census Commissioner, India, entitled "Consistent correction of census, vital registration, and migration data for all India and the state of Kerala, 1971—81", N.Y. Luther, J.R. Rele, and K. Gopinathan estimate the corrected 1971 census age distribution and corrected net immigration age distributions for the

Transforming Age-Period Data into Cohort-Period Data

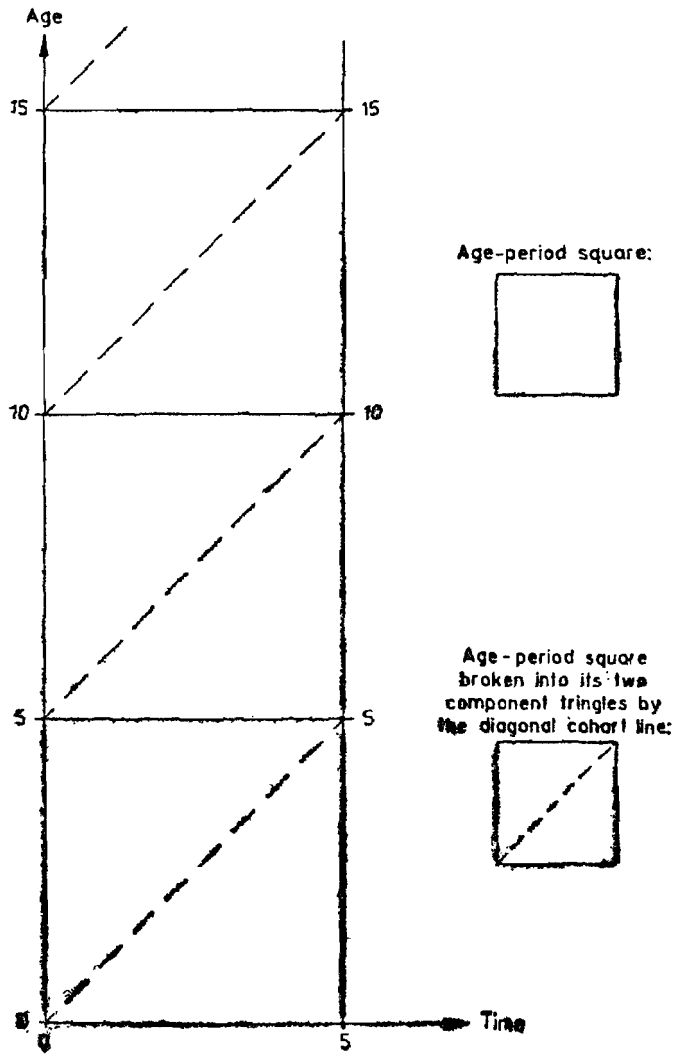


Figure 4

5 year periods 1971—76 and 1976—81 for the state of Kerala as follows:

Age	Estimated 1971 Population	Estimated Net Immigration* 1971—76	1976—81
0	1,616,363	—9,125	—8,802
5	1,516,494	—766	3,260
10	1,435,046	—6,646	—5-666
15	1,154,564	—21,556	—31,073
20	946,388	—28,270	—52,144
25	721,388	—21,040	—45,462
30	618,724	—16,712	—28,005
35	638,703	—15,565	—16,368
40	512,134	—9,991	—9,171
45	472,643	—6,146	—1,758
50	383,758	—2,655	— 483
55	309,547	—847	252
60	244,022	—344	180
65	172,411	—265	97
70+	241,109	—267	—166
Total	10,983,293	—140,192	—195,310

*Number of immigrants (in-migrants) minus number of emigrants (out-migrants).

From the same source, the estimates of life expectancy for Kerala Males for the periods 1971—76 and 1976—81 are about $e_0=62$ and $e_0=65$ years, respectively. Consequently, we use the Males, South Asian Pattern model life tables (United Nations, 1982. *Model Life Tables for Developing Countries*) with life expectancies $e_0=62$ and $e_0=65$ years to calculate the survival rates for Kerala Males during the periods 1971—76 and 1976—81, respectively. (Actually, the estimated life expectancies are $e_0=61.715$ and 64.549, respectively; to calculate survival rates precisely, we should interpolate between life tables having life expectancies 61 and 62 years for 1971—76, and 64 and 65 years for 1976—81, but we shall not bother to do so.) The relevant life tables are attached.

Input Population and Migration
Data for Projection of Kerala Males, 1971

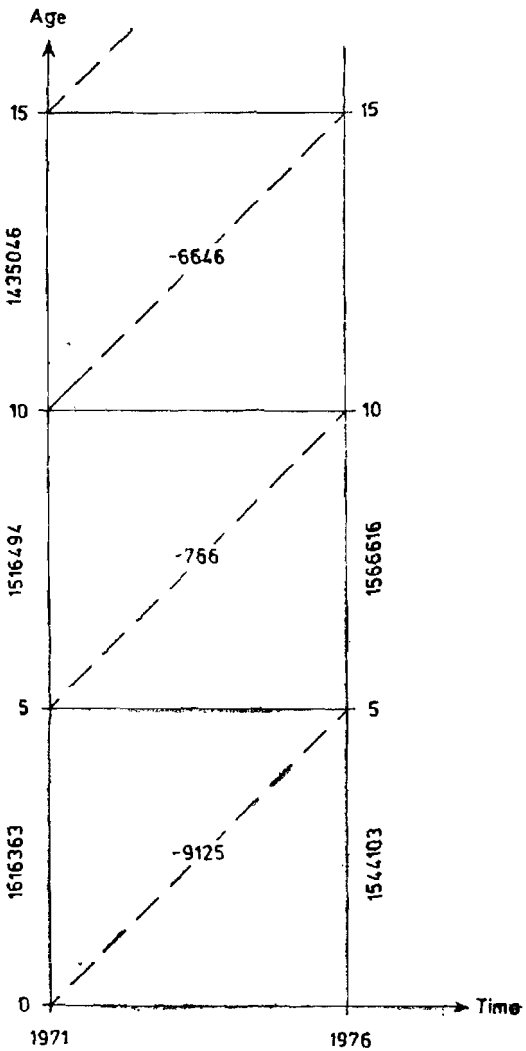


Figure 5

To find survival rates, we use the L(x) column of the life table which gives the person-years lived. We denote person-years lived between exact ages x and x+n by ${}_nL_x$. Note that the life table gives ${}_1L_0$ and ${}_4L_1$ from which we may calculate

$${}_5L_0 = {}_1L_0 + {}_4L_1.$$

For example, for the life table with $e_0 = 62$,

$${}_5L_0 = 94191 + 359015 = 453206;$$

and for the life table with $e_0 = 65$,

$${}_5L_0 = 94923 + 366796 = 461719.$$

We shall now project the estimated 1971 Kerala Males population age distribution (given above) forward to 1976, using the estimated migration figures for 1971-76 (given above) and survival rates implied by the Males, South Asian Pattern model life table for $e_0 = 62$. You may want to project the resulting 1976 population age distribution forward to 1981 by the same method as an exercise using the estimated migration figures for 1976—81 (given above) and survival rates calculated from the Males, South Asian Pattern model life table for $e_0 = 65$. (Incidentally, the estimated number of Kerala male births for 1976—81 from the same source is 1619904.)

In projecting the 1971 Kerala Males population forward to 1976, the notation established earlier will be used. The 1971 Kerala Males population for the 0—4 age group is ${}_nC^0_{m,1} = 1616363$ from above. The survival rate for the age 0—4 population that is implied by the Males, South Asian pattern model life table with life expectation $e_0 = 62$ is $S_{m,1} = {}_5L_5/{}_5L_0 = 440625/453206 = .97224$.

Consequently, the number of the original ${}_nC^0_{m,1} = 1616363$ males age 0—4 in 1971 that survive to 1976 (when they are age 5—9) is

$${}_nC^0_{m,1}S_{m,1} = (1616363)\ (.97224) = 1571493.$$

We need to add to this the contribution of migration in order to find the age 5—9 population in 1976, denoted ${}_nC^5_{m,1}$. Now the number of net immigrants (in-migrants) of ages 0—4 and 5—9 during the period 1971—76 are —9125 and —766, respectively (the minus sign denoting net emigration; i.e., out-migration). Thus,

Preparation of Data for Projection
Formulas for Projection of Kerala Males, 1971
From Male South Asian Life Table With e_0=62

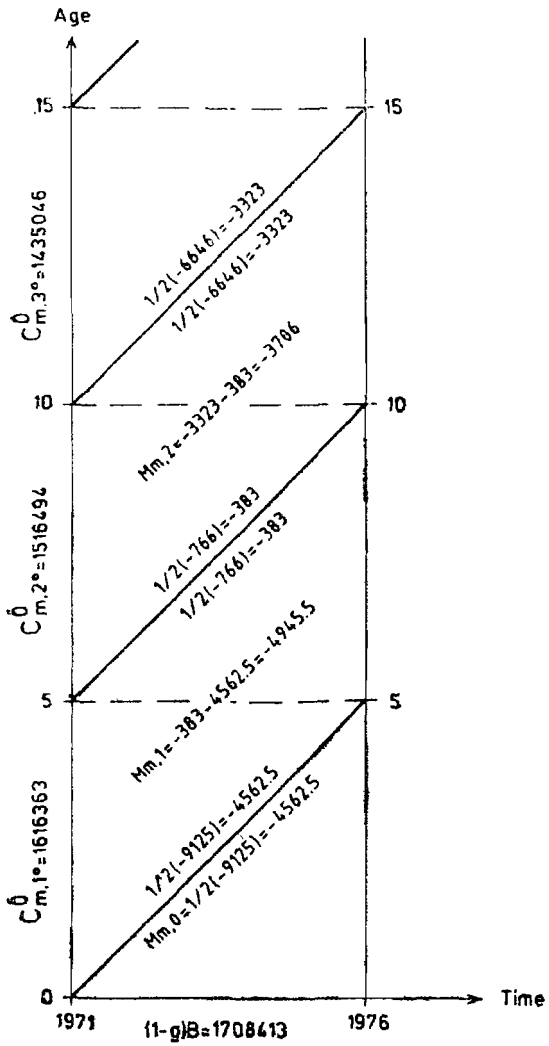


Figure 6

Calculation of Survival Rates for Projection of Kerala Males, 1971

From Male, South Asian Life Table with $e_0 = 62$

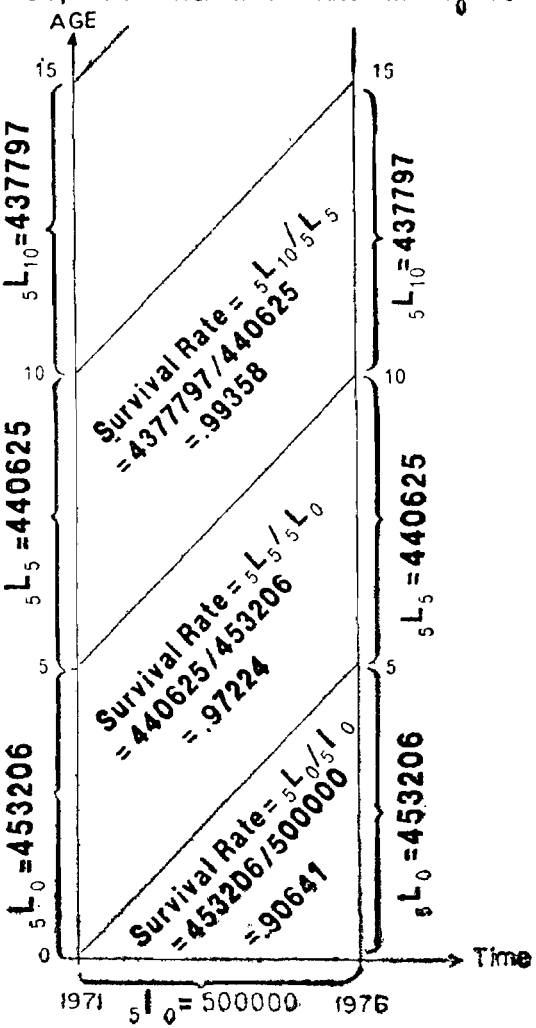


FIGURE-7

assuming uniform migration with respect to age and time, each of these net immigration totals for its square of the Lexis diagram is divided equally into the totals for its two component triangles (formed by the cohort line diagonalizing the square) in order to generate the total net immigration $M_{m,1}$ for the cohort age 0—4 in 1971 (see Lexis diagram of Figure 6). That is,

$$M_{m,1} = 1/2\ (-9125) + 1/2\ (-766) = -4945.5.$$

Thus, assuming as before that migration is distributed uniformly over age and time and that migrants have the same survival rates as non-migrants, the contribution of migration to the age 5—9 population in 1976 is, from an earlier formula (p.56),

$$M_{m,1}\ (1+S_{m,1})/2 = (-4945.5)\ (1+.97224)/2 = -4877.$$

Thus the total population of the 5—9 age—group in 1976 is

$$_1C^5{}_{m,1} = C^0_{m,1}\ S_{m,1} + M_{m,1}\ (1+S_{m,1})/2$$
$$= 1571493 - 4877 = 1566616$$

from our previous calculations.

The projection of the 1971 Kerala Male population for each of the other age-groups 5—9, 10—14, 15—19,...., 70+ to its population in 1976 (when each group is five years older) is carried out exactly as with the 0—4 age-group. (Recall that the survival rate for the last cohort, age 70+ in 1971 is T_{75}/T_{70} so is obtained from the T (X) column of the life table.) You may want to carry out the projection for one or more of these age-groups as an exercise.

It remains to project the births that occurred during the period 1971—76. They, of course project to the age 0—4 population in 1976, denoted $C^5m_{,0}$. The microcomputer program that we shall use asks for the age-specific birth (fertility) rates for women ages 15—49 by 5-year age-groups. Using these rates in conjunction with the age distribution of women, the program calculates the total births B by the earlier formulas (1) and (2), then calculates feamle and male births individually as gB and (1=g)B, respectively, where g is the proportion of births that are females.

Our source listed above gives no age-specific birth rates, but rather an estimate of 1708413 male births for 1971—76 so we shall start with that:

$(1-g)B=1708413.$

Now the survival rate for this cohort is,

$S_{m,0}={}_5L_0/5.\,l_0=453206/500000=.90641$

by earlier equation(6) so that the number of the original $(1-g)B=1708413$ births during the period 1971−76 that survive to 1976 (when they are age 0−4) is

$(1-g)B.\quad S_{m,0}=(1708413)\ (.90641)=1548523$

by earlier equation (4).

Again, we need to add to this the contribution of migration in order to find the age 0—4 population in 1976, denoted $C^5m,0$. Now the number of net immigrants of ages 0—4 during the period 1971-76 is −9125 from above. Thus, again assuming uniform migration with respect to age and time, half of these −9125 net immigrants make up the total net immigration $M_{m,o}$ for the 1971—76 birth cohort, i.e., the cohort age 0—4 in 1976 (see Lexis diagram of Figure 6). That is,

$M_{m,o}=1/2(-9125)=-4\,62.5.$

Thus, the contribution of migration to the age 0—4 population in 1976 is, from an earlier formula (p.59),

$M_{m,0}\ (2+S_{m,0})/3=(-4562.5)\ (2+.90641)/3=-4{,}420.$

Thus the total popultion of the 0—4 age-group in 1976 is

$$C^5{}_{m,0}=(1-g)BS_{m,0}+M_{m,0}(\,2+S_{m,0}\,)/3$$
$$=1548523-4420=1544103.$$

from our previous calculations.

As mentioned before, you are invited to calculate the projections for the other age-groups (and on to 1981, if you are really eager). So that you may check your calculations, the answers are given in Table 1 on the next page. But you should first do the calculations without looking at the answers.

Table 1. Calculations Involved in Projecting Kerela Males from the 1971 Census Forward to 1976

Cohort No. (c)	Age in 1971	Births during 1971-76 or Population in 1971 (1-g) B or $C^0_{m,c}$)	Survival Rate ($S_{m,c}$)	Net Immigration ($M_{m,c}$)	Age in 1976	Population in 1976 ($C^5_{m,c}$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	To be born	1,708,413	.90641	—4562.5	0—4	1,544,103
1	0—4	1,616,363	.97224	—4945.5	5—9	1,566,616
2	5—9	1,516,494	.99358	—3706	10—14	1,503,064
3	10—14	1,435,046	.99560	—14101	15—19	1,414,662
4	15—19	1,154,564	.99461	—24913	20—24	1,123,495
5	20—24	946,388	.99345	—24655	25—29	915,615
6	25—29	721,388	.99191	—18876	30—34	696,752
7	30—34	618,724	.98924	—16138.5	35—39	596,015
8	35—39	638,703	.98405	—12778	40—44	615,840
9	40—44	512,134	.97533	—8068.5	45—49	491,531
10	45—49	472,643	.96023	—4400.5	50—54	449,533
11	50—54	383,758	.93709	—1751	55—59	357,920
12	55—59	309,547	.90152	—595.5	60—64	278,497
13	60—64	244,022	.85023	—304.5	65—69	207,193
14	65—69	172,411	.78203	—266	70—74	134,594
15	70+	241,109	.59018	—133.5	75+	142,192

United Nations Model Life Tables—Males

South Asian Pattern

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.08987	.08444	100000	8444	93965	6100000	61.000	0.285
1	.01073	.04174	91556	3822	356281	6006035	65.600	1.399
5	.00193	.00961	87734	843	436563	5649754	64.396	2.500
10	.00087	.00434	86891	377	433513	5213191	59.997	2.500
15	.00107	.00533	86514	461	431452	4779678	55.247	2.576
20	.00127	.00633	86053	545	428945	4348226	50.530	2.578
25	.00158	.00785	85508	671	425921	3919281	45.835	2.587
30	.00195	.00973	84837	825	422216	3493360	41.177	2.614
35	.00278	.01379	84012	1158	417342	3071144	36.556	2.654
40	.00421	.02085	82854	1727	410245	2653802	32.030	2.671
45	.00658	.03240	81126	2629	399538	2243558	27.655	2.682
50	.01079	.05264	78497	4132	382866	1844020	23.492	2.672
55	.01672	.08046	74365	5983	357800	1461154	19.648	2.656
60	.02694	.12662	68382	8658	321385	1103355	16.135	2.629
65	.04075	.18549	59724	11078	271886	781970	13.093	2.587
70	.06146	.26684	48646	12981	211189	510083	10.486	2.532
75	.08778	.35885	35665	12798	145792	298894	8.381	2.458
80	.12092	.45951	22867	10507	86899	153101	6.695	2.389
85	.18669	******	12359	12359	66203	66203	5.357	5.357

Unitrd Nations Model Life Tables—Males—*Contd.*

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.08469	.07977	100000	7977	94191	6200000	62.000	0.272
1	.00977	.03812	92023	3508	359015	6105809	66.351	1.413
5	.00177	.00881	88515	780	440625	5746793	64.925	2.500
10	.00080	.00401	87735	352	437797	5306168	60.479	2.500
15	.00099	.00494	87383	432	435871	4868371	55.713	2.578
20	.00118	.00587	86952	511	433521	4432500	50.977	2.579
25	.00146	.00730	86441	631	430681	3998979	46.263	2.587
30	.00182	.00905	85810	776	427198	3568298	41.584	2.615
35	.00259	.01289	85034	1096	422600	3141100	36.939	2.657
40	.00396	.01962	83938	1647	415858	2718500	32.387	2.675
45	.00624	.03074	82291	2530	405600	2302642	27.982	2.686
50	.01031	.05036	79761	4017	389469	1897041	23.784	2.676
55	.01610	.07757	75744	5876	364969	1507572	19.904	2.660
60	.02608	.12284	69868	8582	329027	1142603	16.354	2.633
65	.03959	.18070	61286	11074	279749	813576	13.275	2.591
70	.05991	.26101	50212	13106	218772	533827	10.632	2.537
75	.08587	.35258	37106	13083	152348	315055	8.491	2.464
80	.11884	.45374	24023	10900	91721	162706	6.773	2.395
85	.18487	******	13123	13123	70985	70985	5.409	5.409

United Nations Model Life Tables—Males—*Contd.*

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.07960	.07516	100000	7516	94427	6300006	63.000	0.259
1	.00887	.03468	92484	3207	361680	6205579	67.099	1.427
5	.00162	.00805	89276	718	444585	5843899	65.459	2.500
10	.00074	.00369	88558	327	441972	5399314	60.969	2.500
15	.00092	.00457	88231	403	440178	4957342	56.186	2.579
20	.00109	.00544	87828	477	437983	4517164	51.432	2.580
25	.00136	.00677	87350	591	435325	4079181	46.699	2.588
30	.00168	.00839	86759	728	432061	3643856	42.000	2.617
35	.00242	.01202	86031	1034	427738	3211795	37.333	2.660
40	.00372	.01842	84998	1566	421352	2784057	32.755	2.678
45	.00590	.02910	83432	2428	411552	2362704	28.319	2.691
50	.00984	.04810	81004	3896	395983	1951153	24.087	2.680
55	.01548	.07468	77108	5758	372089	1555169	20.169	2.664
60	.02522	.11901	71350	8492	336683	1183080	16.581	2.637
65	.03841	.17582	62858	11051	287709	846397	13.465	2.595
70	.05832	.25504	51807	13213	226548	558688	10.784	2.541
75	.08392	.34612	38594	13358	159169	332140	8.606	2.470
80	.11671	.44776	25236	11300	96816	172971	6.854	2.401
85	.18300	******	13936	13936	76155	76155	5.465	5.465

United Nations Model Life Tables—Males—*Contd.*

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.07461	.07063	100000	7063	94671	6400003	64.000	0.246
1	.00801	.03142	92937	2920	364274	6305331	67.845	1.440
5	.00147	.00733	90017	659	448438	5941057	65.999	2.500
10	.00068	.00339	89358	303	446033	5492619	61.468	2.500
15	.00084	.00421	89055	375	444369	5046585	56.668	2.580
20	.00101	.00501	88680	445	442325	4602216	51.897	2.580
25	.00125	.00626	88236	552	439847	4159891	47.145	2.588
30	.00156	.00775	87684	680	436799	3720044	42.426	2.618
35	.00225	.01117	87004	972	432749	3283245	37.737	2.663
40	.00348	.01725	86032	1484	426720	2850496	33.133	2.682
45	.00557	.02748	84548	2323	417384	2423776	28.667	2.695
50	.00937	.04584	82225	3769	402398	2006391	24.401	2.685
55	.01485	.07177	78456	5630	379149	1603993	20.445	2.668
60	.02435	.11514	72825	8385	344343	1224844	16.819	2.641
65	.03722	.17084	64440	11009	295762	880501	13.664	2.599
70	.05671	.24892	53431	13300	234518	584738	10.944	2.546
75	.08193	.33945	40131	13622	166266	350220	8.727	2.476
80	.11453	.44155	26508	11705	102201	183954	6.939	2.408
85	.18108	******	14804	14801	81753	81753	5.523	5.523

United Nations Model Life Tables—Males—*Contd.*

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.06971	.06617	100000	6617	94923	6500001	65.000	0.233
1	.00721	.02833	93383	2645	366796	6405078	68.589	1.454
5	.00133	.00664	90738	603	452182	6038282	66.547	2.500
10	.00062	.00309	90135	279	449978	5586100	61.975	2.500
15	.00078	.00387	89856	348	448440	5136122	57.159	2.581
20	.00092	.00461	89509	412	446545	4687682	52.371	2.581
25	.00116	.00576	89096	513	444243	4241137	47.602	2.589
30	.00143	.00714	88583	632	441408	3796894	42.863	2.619
35	.00208	.01035	87950	910	437627	3355486	38.152	2.666
40	.00325	.01611	87040	1402	431955	2917860	33.523	2.686
45	.00524	.02588	85638	2217	423090	2485905	29.028	2.699
50	.00890	.04359	83421	3636	408706	2062814	24.728	2.690
55	.01422	.06884	79785	5493	386142	1654109	20.732	2.672
60	.02347	.11122	74293	8263	352001	1267967	17.067	2.645
65	.03602	.16578	66030	10946	303906	915966	13.872	2.603
70	.05507	.24265	55083	13366	242687	612061	11.112	2.551
75	.07989	.33256	41718	13874	173653	369374	8.854	2.482
80	.11228	.43509	27844	12114	107897	195721	7.029	2.414
85	.17910	******	15729	15729	87824	87824	5.583	5.583

United Nations Model Life Tables—Males—*Contd.*

AGE	M(X)	Q(X)	I(X)	D(X)	L(X)	T(X)	E(X)	A(X)
0	.06492	.06179	100000	6179	95181	6600000	66.000	0.220
1	.00646	.02542	93821	2385	369243	6504819	69.332	1.467
5	.00120	.00599	91436	548	455812	6135576	67.102	2.500
10	.00056	.00282	90888	256	453802	5679764	62.492	2.500
15	.00071	.00354	90632	321	452387	5225962	57.661	2.583
20	.00085	.00422	90312	381	450637	4773575	52.857	2.582
25	.00106	.00529	89931	476	448507	4322938	48.070	2.590
30	.00131	.00655	89455	586	445881	3874432	43.312	2.621
35	.00192	.00956	88869	849	442365	3428551	38.580	2.669
40	.00302	.01499	88020	1319	437050	2986186	33.926	2.690
45	.00492	.02431	86700	2108	428661	2549136	29.402	2.704
50	.00843	.04135	84592	3498	414896	2120475	25.067	2.694
55	.01360	.06590	81094	5344	393055	1705579	21.032	2.677
60	.02259	.10725	75750	8124	359646	1312524	17.327	2.649
65	.03480	.16062	67626	10862	312133	952877	14.090	2.607
70	.05341	.23620	56764	13408	251056	640744	11.288	2.556
75	.07781	.32544	43356	14110	181342	389689	8.988	2.488
80	.10996	.42836	29246	12528	113926	208347	7.124	2.421
85	.17706	******	16718	16718	94421	94421	5.648	5.648

Software for microcomputer:

(a) FIVFIV from **Population Council**

Description: Population projection at five-year intervals by the cohort-component method, modified by projecting the effects of migration integrally with those of fertility and mortality.

Input data needed:

(i) Initial population at some point in time by sex and by 5-year age groups 0—4, 5—9, 10—14,...(maximum of 16 age groups including final open-ended age group).

(ii) Expectation of life at birth e° by sex for each of the seven 5-year periods 0—5, 5—10..., 30—35 years after the time of the initial population and selection of the East, West, North, or South family from the Coale-Demeny model life tables, the South Asian or Far Eastern family from the United Nations *Model Life Tables for Developing Countries*, or a user-defined family of life tables; or selection of level by sex of one of the four regional Coale-Demeny families for each of the seven 5-year periods.

Alternatively: For split mortality option (different levels for below and above age 5), infant mortality 1000_1q_0 or level of a regional family by sex for below age 5, and expectation of life at age 5 e_5 or level of regional family by sex for above age 5, for each of the seven 5-year periods.

(iii) Age-specific fertility rates by 5-year age groups of women ages 15—49 for each of the seven 5-year periods.

(iv) Age-specific net immigration (in-migration) by sex and by the same age groups as for the initial population, for each of the seven 5-year priods.

(b) SINSIN from **Population Council**

Description: Transforms results of *FIVFIV* projection (see above) into annual estimates of populatiion arranged by single-year or other age groupings.

Input data needed: Same as for FIVFIV (see above).

Reference: Shorter, Frederic C., David Pasta, and Robert Sendek. 1987. *Computational Methods for Population Projections: With Particular Reference to Development Planing*, First Edition with Supplement Added. New York: The Population Council.

B. Lecture Note of Shri K. S. Natarajan, Deputy Registrar General, (Demography)

Fertility and Child Mortality Estimation from the Census Data

In the recent Indian censuses, questions relating to fertility have been canvassed. In the 1971 census questions on age at first marriage and births during last one year were canvassed for all currently married women. In the 1981 census, 4 questions relating to fertility were canvassed. These were age at marriage, number of children ever born sexwise, number of surviving children sexwise and whether any child was born during last one year. The first three questions were canvassed for all ever married women. For reasons of operational convenience, the question on births during last one year was canvassed for currently married women only. In the 1991 census also it is proposed to canvass the same questions as was done during 1981.

2. Apart from these questions, in the 1981 census instructions were laid down that for all children below age ten, the mother of the child who is living in the household at the time of census must be identified by circling the serial number of the mother in the household schedule. This was intended to provide estimates of fertility by "own-child" method. In the 1991 census this has not been adopted. This is not because of the unacceptability of the own-child method, but because a decision has been taken that the household schedule would be processed entirely manually, while the individual slip would be processed on computer.

3. The tables relating to fertility have been published as the F series tables of the Census of India 1981. In all, about 28 tables were prepared based on the above questions. In the 1991 census it is proposed to prepare about 18 tables for general population. In addition, 4 tables would be prepared for scheduled castes and scheduled tribes.

Child mortality estimates:

4. Number of children ever born and number of children surviving sex wise, have been tabulated at district level by age of mother. At state level, similar tables have been prepared by religion of the mother, educational level of the mother and the occupation of the mother (if she is a main worker). Tables are available separately for each of the six main religious, namely Hindus, Muslims, Christians, Sikhs, Buddhists, Jains and 'Others'. The educational level of the mother has been classified as illiterate, literate but below middle, middle but below matric, matric but below graduate and graduate and above.

5. Based on the data on children ever born and children surviving tabulated by the age of mother, estimates of child mortality, q(1), q(2), q(3) and q(5) have been prepared in the 1981 census for 402 districts of India. The estimates have been worked out by using Brass technique. The actual equations for estimation were based on Trussel's equations using South Model life tables. Child mortality estimates have been prepared sex wise separately for rural and urban areas. In the absence of reliable civil registration system, these estimates provide usable data at district level. These have been published in the volume "Child Mortality estimates of India, occasional paper No. 5 of 1988: Census of India 1981".

6. The estimates of Child mortality derived by indirect estimation techniques compare well with those derived from the Sample Registration System. q(1) which is closer to the infant mortality rate works out to be 115 for India as against the Sample Registration System estimate of 114 for the year 1980. The census based estimates of IMR are 123 for rural areas and 67 for urban areas: the corresponding Sample Registration System estimates being 124

and 65. There is hardly any difference between the Sample Registration Scheme and census estimates of infant mortality for the year 1980. However, the estimates of q(5) derived from census are much lower than those obtained from sample Registration System. The estimates of q(5) for the period 1976-80 based on Sample Registration System are 181 and 206 respectively for males and females. The corresponding figures based on Brass' techniques are 147 and 157 only. Probably, the estimates of q(5) based on the data on number of children born and surviving reported by women aged 30—34, are under-estimates. In table 1, Sample Registration System and census estimates of q(1) and q(5) for the major states of India have been presented. The estimates of q(1) from census and Sample Registration System are quite close to each other in case of Andhra Pradesh, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Rajasthan and Tamil Nadu.

7. To check the internal consistency of the estimates worked out by the indirect estimation technique, a comparison has been made between q(2) and q(5) estimates for various districts. q(2) has been divided into 7 ranges viz., less than 71, 71—100, 101—120, 121—145, 146—170, 171—200 and more than 200. Corresponding to these ranges of q(2), the ranges q(5) as per the South Asian Model life tables are less than 81, 81—120, 121—145, 146—185, 186—210, 211—250 & more than 250.

8. The statement below shows the consistency between q(2) and q(5) estimates in various districts.

CONSISTENCY BETWEEN q(2) AND q(5) ESTIMATES IN VARIOUS DISTRICTS

q(5)	Less than 81	81—120	121—145	146—185	186—210	211—250	More than 250
q(2)							
Less than 71	20	13	—	—	—	—	—
71—100	—	68	21	—	—	—	—
101—120	—	1	68	21	1	—	—
121—145	—	—	6	66	7	—	—
146—170	—	—	—	18	43	6	—
171—200	—	—	—	—	5	23	2
More than 200	—	—	—	—	—	6	7

9. Out of 402 districts for which estimates have been worked out here, estimates for 295 fell into the proper ranges. In 71 out of the remaining districts, q(5) is higher compared to the range of q(2). Among those 71 districts, q(5) is very close to the upper limit of the corresponding range in 56 districts. Probably in the remaining 15 districts mortality has declined during the intervening period of or it may be due to bad data. Out of these 15 districts 9 are in the comparatively smaller states of Meghalaya, Sikkim and Arunachal Pradesh, where the data could be faulty because of non-sampling errors. In 36 districts, estimated q(5) is low compared to q(2) but in fact it is only in 5 districts that q(5) seems relatively low compared to q(2) as in the remaining 31 districts q(5) is very close to the lower limit of the corresponding range. Thus, only in 20 districts thoughout the country q(5) estimates are not consistent with the q(2) estimates. The inconsistencies are so small, that it canbe said that q(2) and q(5) estimates are generally very consistent between themselves in most of the districts.

10. Based on the child mortality estimates, two maps have been prepared. The first map shows the child mortality from birth to age 2, i.e. q(2), per 1000 live births and its differentials in different regions. This map brings out the spatial distribution of child mortality. The second map shows the male female differentials in child mortality. For this purpose the ratio of q(5) estimated for males to that of females multiplied by 100 has been used as an index. This map clearly brings out the areas where female child mortality is more than male child mortality.

11. A further analysis of the q(2) and q(5) estimates for males and females indicates that in 136 districts of the country child mortality q(2) and q(5) are higher for females than males. Furhter, out of 260 districts where in q(2) for females was less than q(2) for males, in 88 districts female child mortality, q(5), becomes higher than that of male child mortality , q(5).

Estimates of fertility:

12. The data on number of children ever born were combined with that on births during last year to estimate fertility by P/F ratio

method. The values of P/F ratios for various age groups 15—19, 20—24 and 45—49 were examined for any systematic trend. The age specific fertility rates derived from the data on births during last year were than adjusted by P_3/F_3 or P_2/F_2. In most of the cases P_3/F_3 was used to adjust.

13. Unlike the estimates of child mortality, the estimates of fertility derived by using P/F ratio method are known to suffer from certain bias. Fertility estimates obtained by applying the method when either marital fertility or age at marriage has been changing rapidly in the recent years may be subject to bias, since it would no longer be valid to assume that the pattern of fertility reflected by average parity is equal to that indicated by current fertility. In the Indian situation, there has been very little fertility decline in younger ages. Wherever family planning has been adopted, it is mostly the terminal method of sterilisation adopted by older women. Though age at marriage is also increasing, the pace of increase has not been very rapid. In fact, most of the increase in age at marriage is taking place in the age group 15—19. In view of this, it is felt that use of P_3/F_3 as an adjustment factor seems justified in most of the cases. Despite this, if the P/F ratios indicated an increasing trend, the estimates for such districts are considered as over estimates. Out of 402 districts of the country (excluding Assam) in about 70 districts the estimates derived by this method are considered over estimates.

14. Table 2 shows the crude birth rates derived on the basis of P/F ratio method and those based on Sample Registration system for the year 1980. The Sample Registration System estimates are available only at state level. Hence, the comparison is limited to state level estimates. The table shows the Sample Registration System birth rates adjusted for under reporting. The estimates of under reporting are based on an intensive enquiry conducted in a number of major states of India on a 10 percent Sub sample of Sample Registration System units.

15. For India as a whole, Sample Registration System estimates the crude birth rate at 33·7 for 1980. The intensive inquiry conducted by the Office of the Registrar General, India indicated that

the birth rate was under estimated by 3·16 percent. Adjusting for this the crude birth rate for 1980 based on Sample Registration System may be put around 34·8/1000. This is very close to the value of 34·7 obtained by P/F ratio method. However, the agreement is not uniform or so close in all the states. In the states of Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Rajasthan & Uttar Pradesh both the estimates agree closely. In case of Bihar, the estimate derived from census by P/F ratio techniques is slightly lower than that of sample Registration Scheme. In other states, the agreement is not very close and the estimates based on P/F ratio are higher.

Proposed analysis for 1991 Census:

16. In the 1991 census also tabulation similar to 1981 census have been provided for. It would, therefore, be possible to estimate the levels of child mortality and trends over time by comparing the estimates with those obtained in 1981.

17. As regards fertility, it is felt that the P/F ratio method using 1991 Census data alone may not give usable estimates, since, during the decade fertility seems to have further declined. The fertility estimates for the intercensal period as a whole may be obtained by comparing the period fertility rates derivable from the questions on births during the last one year, with the average parities for a hypothetical birth cohort. In this method, described in U.N. Manual 10, the average parities for a hypothetical inter census cohort would be derived first using 1981 and 1991 census data on children ever born. The age specific fertility rates derived from 1981 census and 1991 consus would be used to provide estimates of fertility pattern during the inter-census period and the estimation of average parity equivalents for hypothetical inter survey cohort. The P/F ratio method would then be applied and an adjustment factor selected after examining the various ratios.

18. At the state level, since ASFR's based on Sample Registration Scheme would be available annually, this data would be used to estimate the completeness of birth registration. Estimates so derived at state level would be compared with similar estimates

obtained by the method described in previous para to get an idea of the consistency of the results.

19. One major limitation of the above method to estimate fertility parameters at district level would be the effect of migration. If migrants have a different pattern of fertility than the non-migrants, then the parity increments may not be really representative. One way to study this would be to tabulate similar data for inter-district migrants. If this is not possible for all the districts this may be attempted at least for some districts which are known to receive a number of in migrants. This, however, would require a special tabulation and can be attempted only after the main census tabulations are over.

TABLE 1: STATEMENT SHOWING A COMPARISON BETWEEN SRS AND CENSUS ESTIMATES q(1) AND q(5)

State	q(1)						q(5)					
	Census			SRS(IMR 1980)			Census			SRS (1976-80)		
	M	F	P	M	F	P	M	F	P	M	F	P
1	2	3	4	5	6	7	8	9	10	11	12	13
Andhra Pradesh .	100	82	91	102	82	92	143	135	139	173	170	172
Bihar . .	95	94	94	—	—	—	131	153	141	—	—	—
Gujarat .	81	84	84	112	114	113	119	129	124	193	212	202
Haryana .	87	119	94	95	113	103	125	153	138	150	202	175
Himachal Pradesh .	101	89	92	—	—	87	142	136	139	132	163	146
Jammu & Kashmir .	78	78	78	—	—	72	114	117	115	123	135	128
Karnataka .	87	74	81	71	71	71	143	140	142	136	147	142
Kerala .	55	48	52	44	36	40	85	76	80	71	69	70
Madhya Pradesh .	158	140	150	144	139	142	193	201	197	223	241	231
Maharashtra	96	89	92	73	78	75	146	144	145	137	150	143
Orissa .	119	111	115	143	143	143	181	176	179	193	207	200
Punjab .	74	79	77	89	94	89	104	118	111	132	167	149
Rajasthan .	114	114	114	105	105	105	166	186	176	206	200	203
Tamil Nadu	89	82	86	94	91	93	134	131	132	167	171	169
Uttar Pradesh	131	128	130	132	168	159	174	200	190	242	317	279
West Bengal .	103	87	95	—	—	—	123	125	124	—	—	—
INDIA .	122	108	115	113	115	114	147	157	152	181	206	193

TABLE 2: BIRTH RATES FROM DIFFERENT SOURCES FOR INDIA & MAJOR STATES

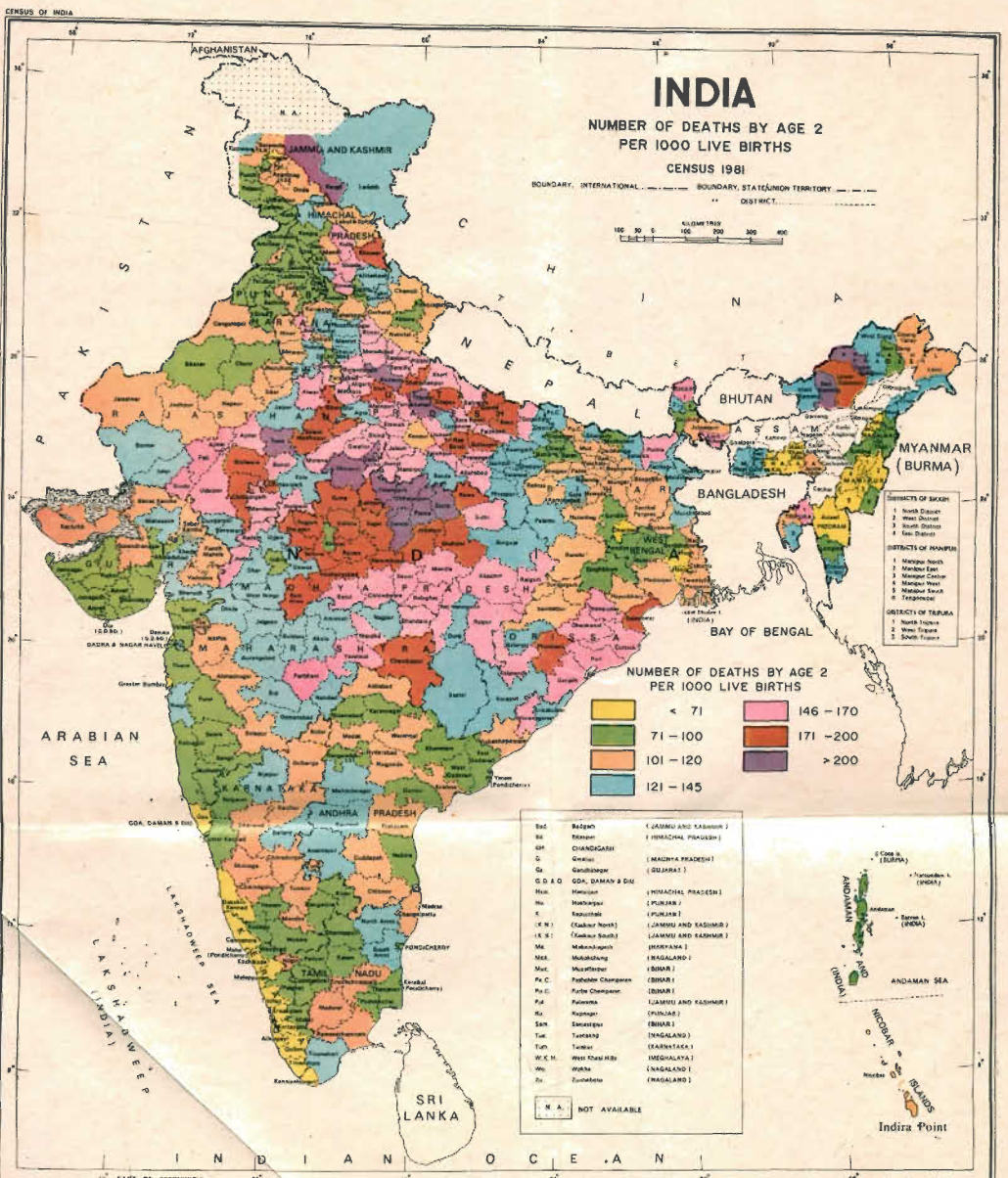
India/State	1978		1980		Using P/F Technique 1980
	Observed	+Adjusted	As per S.R.S.	Adjusted as per 1980-81 survey@	
1	2	3	4	5	6
INDIA	33.3*	34.1*	33.7	34.70	34.9
Andhra Pradesh	33.6	34.4	31.0	33.10	33.2
Assam	30.8	32.4	31.9	35.00	—
Bihar	31.2	N.A.	37.8	N.A.	36.9
Gujarat	35.8	36.0	35.8	35.48	36.6
Haryana	33.5	36.9	37.2	37.31	37.5
Himachal Pradesh	27.3	28.2	32.1	32.64	36.3
Jammu & Kashmir	31.8	35.5	31.1	N.A.	38.6
Karnataka	29.2	34.3	27.6	31.43	35.4
Kerala	25.2	26.3	26.8	26.92	28.7
Madhya Pradesh	37.2	38.7	37.1	37.23	38.0
Maharashtra	26.9	27.5	29.3	29.57	31.8
Orissa	32.9	36.1	31.6	N.A.	35.2
Punjab	29.4	31.5	29.9	30.69	35.8
Rajasthan	35.5	39.6	38.7	39.38	41.0
Tamil Nadu	28.8	31.9	27.9	28.40	32.0
Uttar Pradesh	40.4	42.5	39.4	40.42	39.1
West Bengal	28.4	N.A.	31.7	N.A.	34.7

*Excludes Bihar and West Bengal.

Source: +1978 Adjusted: Estimates of fertility and child mortality by indirect methods—Census of India 1981, Occasional Paper No. 1 of 1983.

@1980 Report on the intensive enquiry conducted in a sub-sample of SRS Units, Census of India 1981, Occasional Paper No. 2 of 1983.

CENSUS OF INDIA



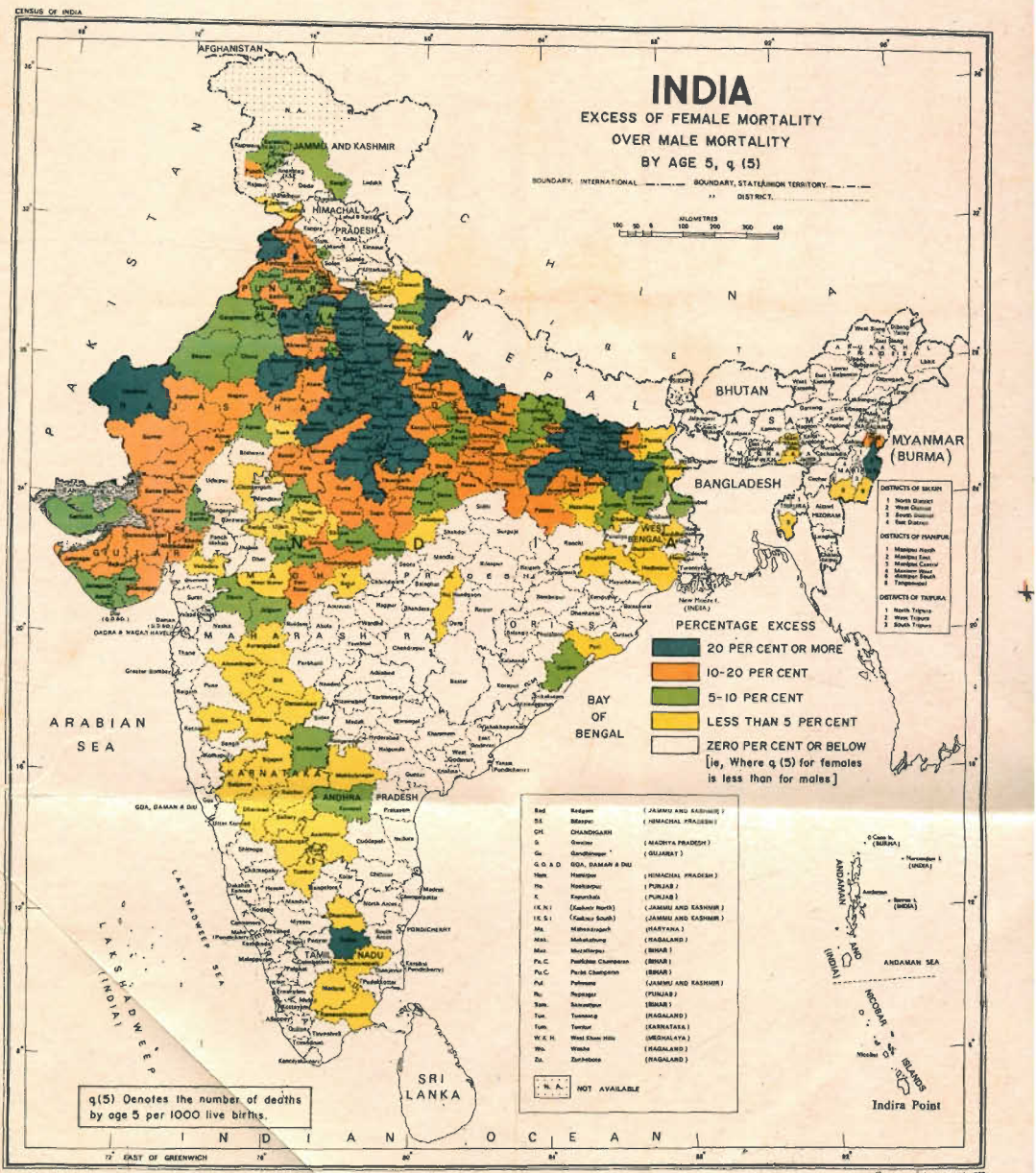
Based upon Survey of India map with the permission of the Surveyor General of India.
The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.

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CENSUS OF INDIA



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C. LECTURE NOTE OF SHRI V. S. SWAMY, DEPUTY REGISTRAR GENERAL (VITAL STATISTICS)

A -ESTIMATES OF FERTILITY

(i) Regression estimate by Palmore (1978)

1.1 The method was evolved by Bouge & Palmore (1964) and subsequently revised by Palmore (1978). Using data from around 1970 round of population censuses, the method originally proposed by Bouge and Palmore was updated. This method essentially takes into account data from censuses and vital statistics of various countries and establishes regression equations for estimating direct fertility measures from indirect fertility measures. As indicated in the handout, each country was classified into one of six classes on the basis of careful evaluation of the data available and whether or not the vital statistics were complete or so. The appropriateness of the approach used in generating regression equations were checked and tested.

1.2 The equation used to estimate TFR using SRS data for India and major states belongs to Type I category and is of the form:

TFR = 13 .5277 IMR + 11 .1042 CWR − 176 .4889 CP − 6 .4698 PEM + 12 .0405.

CWR = Ratio of children aged 0—4 years per 1000 women aged 15—49.

CP = Percentage of population aged 0—4 years.

PEM = Percentage ever-married of women aged 20—24 years.

(ii) Gunasekaran-Palmore method (1984)

1.3 Another method that was applied to SRS data relates to Gunasekaran and Palmore (1984). This method takes into account the momcnts and cumulants of the female age distribution together with the expectation of life at birth for females. The regression equation used in the model is:

$$\text{Log GRR} = 9.65566 - 0.37613045 \log e_0^f + 6.08957 \log \text{CVAG} - 0.56680627 \log K_3 - 0.74030 \log \beta 2.$$

Where:

CAVG $= \sigma/\mu_1$ (σ stands for SD and μ stands fpr mean of the female age distribution)

$K_3 = \mu_3$, third moment about mean.

$\beta_1 = K_3^2/\sigma^6$, $\beta_2 = K_4/\sigma^4 + 3$

$K_4 = \mu_4 - 3\sigma^4$

$e_0^f =$ expectation of life at birth for females.

1.4 Estimates of TFR obtained by the two methods are presented in the statement separately for 1978 and 1988 making use of SRS data. It is seen that SRS estimates for 1978 are close to the estimates using Gunasekaran and Palmore method in all the states except Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan and Uttar Pradesh. In the case of Kerala, Madhya Pradesh and Uttar Pardesh, the SRS estimates are in line with the estimates using Palmore method. The SRS estimates for Punjab lies between the two regression estimates. The estimates for Karnataka and Rajasthan are higher than the two regression estimates. The estimate for Maharashtra is under-stated. For the year 1988, the estimates for SRS are in conformity with the estimates given by Gunasekaran and Palmore method in all states except Andhra Pradesh, Jammu & Kashmir, Kerala and Tamil Nadu. The SRS estimate for Jammu & Kashmir is close to the estimate using Palmore method. The SRS estimates for Andhra Pradesh, Kerala and Tamil Nadu are low in relation to the regression estimates for 1988. The family planning inputs in these states are high. Though apparently the SRS estimates are lower in relation to regression estimates, it can also be debated whether the recent changes in fertility brought about by family planning are reflected in the estimates. A positive conclusion can be obtained only when more data for future years are available. It is also observed that

the current estimates using Palmore method are higher than those obtained by Gunasekaran-Palmore method possibly indicating that with the passage of time and with rapid demographic transition as experienced by developing countries, the regression co-efficients may not be fully reflecting the current situation.

(iii) Rele's method (1967, 1987)

1.5 Another method applied to SRS data for estimating fertility relates to Rele (1967). The method essentially entails inference of fertility level from child-women ratio (CWR) based on an existence of a linear relationship between CWR and GRR among populations at any given level of mortality. The co-efficients of the regression equation for estimating GRR from CWR have been derived and tabulated from stable population for different levels of mortality. This method was further refined (1987) for situations where there is misreporting of ages in the younger age groups. The refined method combines the two levels and trends in fertility based on the estimates using CWR1 and CWR2 (0—4 & 5—9 age groups) by suitable weights. In the present case the weights used are 0.3 & 0.7.

1.6 The estimates of TFR for 1978 & 1982 based on modified method are shown separately. It is seen that SRS estimates for 1978 are in close agreement with the estimates obtained from the model in the states of Andhra Pradesh, Haryana, Himachal Pradesh, Karnataka, Punjab and Rajasthan. In the case of Gujarat, Madhya Pradesh, Orissa, Tamil Nadu and Uttar Pradesh, the estimates are lower than SRS estimates. In Jammu & Kashmir and Assam, the estimates are higher than those of Gunasekaran-Palmore and SRS. It is likely that the age structure of the female population in the age group 15-49 is affected due to migration and this may affect the estimate derived from the model. The SRS estimate for Maharashtra is under-rated in 1978. The estimate for Kerala is closer to the estimate obtained using Palmore method. In the year 1988, the estimates obtained from the model are close to SRS estimates in the states of Andhra Pradesh, Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Rajasthan and Tamil Nadu. In regard to other states, the estimates are lower than

SRS estimates except Jammu & Kashmir and Assam. The same factor as above may be operating.

B—ESTIMATES OF MORTALITY

1.7 One of the methods considered relates to the technique developed by Mazur for estimating mortality. A series of study undertaken by Mazur explored the connections between life expectancy, crude death rate and percentage of persons aged 65 years and over. This model developed by Mazur based on 1960 USA population for standardising crude death rate loses its validity for values of m_s (standardised CDR) exceeding 25.0. This method was modified by Swanson and Palmore making use of 1960 population of Mexico which overcomes the limitation of the original model of Mazur.

(iv) Swanson & Palmore method

1.8 The regression equation is of the form:

$$1000/e^{\circ} = 14.00679 + (0.22719\ m - 0.14433\ m\ \log_{10}\ p65+)^2$$

The estimates of e° for 1978 and 1988 are shown separately. The SRS estimates of mortality are not under-stated in relation to regression estimates in all the states except Haryana and Uttar Pradesh for 1978 within a reasonable margin of error. A similar pattern is seen for 1988 wherein the SRS mortality estimates are under-stated in Gujarat and Kerala. In the case of Gujarat, there is no indication that fertility is under-rated as seen from regression estimates dealt earlier. In the case of Kerala, the low fertility level in 1988 in relation to regression estimates may be ascribed to the changes in fertility due to family planning in the state which is not possibly reflected in the model. It may also be remembered here that the values of the variables used in the model are based on a small sample which is subject to sampling variability.

(v) Swanson, Palmore and Chitra Sundaram method

1.9 The earlier method was extended to cover expectancy of life by sex. The equations used for males and females are respectively.

$1000/c^{\circ}m = 14.35685 + (0.21339\ m - 0.13534\ m\ \log_{10} p65+)^2$

$1000/e^{\circ}f = 13.65814 + (0.24187\ m - 0.15520\ m\ \log_{10} p65+)^2$

Estimates of life expectancy at birth were worked using SRS data for the years 1978 and 1988 which are ten years apart and given separately.

1.10 The SRS estimates of mortality levels are not under-rated in relation to regression estimates for males for 1978 in all states except Haryana. In regard to females for the year 1978, the states which exhibit under-reporting of mortality in relation to regression model are Haryana and Uttar Pradesh. The SRS estimates for mortality for 1988 in the case of males seem to be under-stated in the states of Andhra Pradesh, Gujarat and Haryana while for females for 1988, low levels of mortality in relation to regression estimates are seen in the states of Gujarat, Haryana and Himachal Pradesh. There is no indication of low fertility recorded in SRS in the states of Gujarat and Haryana for 1988. Although fertility has declined in Andhra Pradesh in 1988, it remains to be seen whether the changes brought about by family planning are reflected in the regression estimates. In the states of Gujarat, Haryana and Himachal Pradesh, the fertility estimates for 1988 are close to the regression estimates indicating no understating of fertility. It may also be pointed out that the values of the para-meters are obtained from a small sample subjected to sampling variability.

(vi) Gunasekaran, Palmore and Gardner method

1.11 This method makes use of age specific mortality rates in the broad age groups 0—4, 5—14, 15—49, & 50+. There are two estimates for each sex. The regression model was evolved using data from several countries for which reliable data are available.

1.12 The regression estimates were worked for SRS data for the years 1978 and 1988. The estimates obtained using regression

are shown separately. It is observed that in some of the states the differences between the estimates of e° which are ten years apart are either too low or too large or decreasing. The main reason for the erratic behaviour of the estimates is due to the fact that the values of ${}_5M_{0/\infty}M_{50}$ or ${}_{35}M_{15\infty}M_{50}$ for the first equation and ${}_{10}M_{5/\infty}M_{50}$ or ${}_{35}M_{15/\infty}M_{50}$ for the second equation need not necessarily move in uni-direction overtime. This model dose not seem to be applicable to Indian data on account of the peculiar pattern of mortality decline possibly not envisaged in the model.

1.13. As for example, it is seen that the estimate of e° for Assam (EST2) for males for 1978 obtained from the regression model is of the same level as in Maharashtra indicating that the mortaliy pattern as obtained by the model is not realistic.

(vii) Rele and Palmore method

1.14 Another method developed by Rele and Palmore takes into account the percentage of deaths aged 50 years & over to total deaths aged 5 years & over and the annual per cent growth of population. The regression equation is represented by:

$e_o = A + B\ p + C\ r$

p~percentage of deaths aged 50 years & over to total deaths aged 5 years & ov

r~per cent annual rate of growth of population.

The regression co-efficients A, B & C have been tabulated for specific values of e_o can be interpolated therefrom.

1.15 It is seen that in some of the states the differences between the regression estimates at two points of time ten years apart are either too low or decreasing both for males and females. It is also seen that in the case of Rajasthan, the values of e°_{o} are almost same as in Assam and Maharashtra for 1978 for both sexes. This is an indication that the mortality pattern represented by the regression model does not seem to depict the true situation.

Coefficients for the estimation of the expectation of life at birth (e_o°)

Preliminary e_o°	Males			Females		
	A	B	C	A	B	C
20	—11.1288	0.8419	5.7429	—12.4016	0.8679	6.2489
30	—12.4398	0.8419	7.0539	—13.9142	0.8679	7.7615
40	—13.1134	0.8419	7.7275	—14.7077	0.8679	8.5550
50	—12.9931	0.8419	7.6072	—14.6457	0.8679	8.4930
60	—11.9166	0.8419	6.5307	—13.3873	0.8679	7.2346
70	—9.5292	0.8419	4.1433	—10.5790	0.8679	4.4263
80	—6.8893	0.8419	1.5034	—7.1260	0.8679	0.9733

The estimate of e_o° is obtained from the equation: $e_o^\circ = A + B.p + C.r$, where p is the percentage of deaths at ages 50 and above to deaths at ages 5 and above, r is the per cent rate of growth of population, and A, B, and C are the coefficients corresponding to the preliminary (or assumed) level of e_o°. The detailed procedure, which is iterative, is explained in the text.

Source: J.R. Rele and James A. Palmore.

TABLE 3 : ESTIMATION OF TOTAL FERTILITY RATE, 1978 AND 1988

State	1978					1988				
	A	B	C*	A—C	B—C	A	B	C*	A—C	B—C
Andhra Pradesh	4.7	4.5	4.5	0.2	0.0	3.8	3.7	3.3	0.5	0.4
Assam	4.9	4.3	4.2	0.7	0.1	4.3	3.9	3.9	0.4	0.0
Bihar	N.A.	N.A.	N.A.	N.A.	N.A.	5.1	5.2	5.4	—.3	—.2
Gujarat	5.2	4.8	4.8	0.4	0.0	4.1	3.5	3.4	0.7	0.1
Haryana	5.9	5.3	5.2	0.7	0.1	4.9	4.1	4.2	0.7	—.1
Himachal Pradesh	4.6@	4.5@	4.5@	0.1	0.0	4.0	3.7	3.7	0.3	0.0
Jammu & Kashmir	4.3	4.6	4.5	—.2	0.1	4.2	4.1	4.4	—.2	—.3
Karnataka	4.1	4.2	4.5	—.4	—.3	3.9	3.7	3.5	0.4	0.2
Kerala	3.0	3.3	3.0	0.0	—.2	2.4	2.5	2.0	0.4	0.5
Madhya Pradesh	5.4	5.2	5.5	—.1	—.3	5.1	4.6	4.7	0.4	—.1
Maharashtra	4.2	4.4	3.6	0.6	0.8	3.8	3.6	3.5	0.3	0.1
Orissa	4.9	4.7	4.9	0.0	—.2	4.5	3.9	3.8	0.7	0.1
Punjab	4.8	3.9	4.3	0.5	—.4	3.7	3.3	3.5	0.2	—.2
Rajasthan	5.4	4.9	5.7	—.3	—.8	4.9	4.8	4.6	0.3	0.2
Tamil Nadu	4.0	3.9	3.9	0.1	0.0	3.2	3.1	2.5	0.7	0.6
Uttar Pradesh	6.3	5.4	6.3	0.0	—.9	5.8	5.1	5.6	0.2	—.5
West Bengal	N.A.	N.A.	N.A.	N.A.	N.A.	4.2	3.8	3.6	0.6	0.2
INDIA	5.0	4.6	4.6	0.4	0.0	4.5	4.1	4.1	0.4	0.0

A—Palmore B—Gunasekaran—Palmore C—SRS

@Refers to the year 1977.

*Adjusted as per available adjustment factors.

TABLE 4 : ESTIMATION OF TOTAL FERTILITY RATE, 1978 AND 1982

State	Year	TFR*	SRS Adj.
Andhra Pradesh	1978	4,3	4.5
	1982	3.9	4.1
Assam	1978	4.6	4.2
	1982	4.5	4.2
Bihar	1978	N.A.	N.A.
	1982	5.5	5.6
Gujarat	1978	4.5	4.8
	1982	3.9	4.2
Haryana	1978	5.0	5.2
	1982	4.5	5.0
Himachal Pradesh	1977	4.4	4.5
	1982	4.1	4.2
Jammu & Kashmir	1978	5.1	4.5
	1982	4.8	4.4
Karnataka	1978	4.3	4.5
	1982	4.0	4.0
Kerala	1978	3.3	3.0
	1982	2.8	2.9

TABLE 4 (*Concld.*)

State	Year	TFR*	SRS Adj.
Madhya Pradesh	1978	4.8	5.5
	1982	4.8	5.3
Maharashtra	1978	4.1	3.6
	1982	3.7	3.9
Orissa	1978	4.4	4.9
	1982	3.9	4.3
Punjab	1978	4.1	4.3
	1982	3.8	4.1
Rajasthan	1978	5.5	5.7
	1982	5.5	5.3
Tamil Nadu	1978	3.6	3.9
	1982	3.3	3.4
Uttar Pradesh	1978	5.5	6.3
	1982	5.2	5.8
West Bengal	1978	N.A.	N.A.
	1982	3.9	4.2
INDIA	1978	4.6	4.6
	1982	4.3	4.6

*Based on Rele's modified method.

TABLE 6 : ESTIMATION OF EXPECTATION OF LIFE AT BIRTH USING SWANSON-PALMORE METHOD (BOTH SEXES COMBINED)

State	1978			1988		
	Est.	SRS	Ratio	Est.	SRS	Ratio
Andhra Pradesh	55.8	53.1	1.05	61.5	63.7	0.97
Assam	51.6	51.1	1.01	55.1	52.7	1.05
Bihar	N.A.	N.A.	N.A.	57.9	56.6	1.02
Gujarat	54.5	52.4	1.04	59.9	62.8	0.95
Haryana	54.9	58.9	0.93	62.0	61.7	1.00
Himachal Pradesh	59.3	56.6	1.05	64.1	64.2	1.00
Jammu & Kashmir	56.7	56.8	1.00	64.4	64.0	1.01
Karnataka	57.8	56.3	1.03	64.4	64.9	0.99
Kerala	66.6	65.5	1.02	68.2	71.3	0.96
Madhya Pradesh	51.3	49.0	1.05	54.0	54.2	1.00
Maharashtra	60.8	56.3	1.08	63.8	64.9	0.98
Orissa	52.7	49.1	1.07	58.4	56.9	1.03
Punjab	62.0	60.5	1.02	65.8	65.7	1.00
Rajasthan	50.0	51.4	0.97	53.9	55.6	0.97
Tamil Nadu	56.5	53.4	1.06	63.3	60.4	1.05
Uttar Pradesh	44.5	46.2	0.96	56.3	53.8	1.05
West Bengal	N.A.	N.A.	N.A.	63.7	61.3	1.04
INDIA	53.7	52.3	1.03	60.2	58.5	1.03

TABLE 8 : ESTIMATION OF EXPECTATION OF LIFE AT BIRTH USING SWANSON, PALMORE AND CHITRA SUNDARAM METHOD

State	M/F	1978			1988		
		Est.	SRS	Ratio	Est.	SRS	Ratio
Andhra Pradesh	M	53.9	52.2	1.03	59.5	62.2	0.96
	F	57.8	54.2	1.07	63.7	65.4	0.97
Assam	M	52.7	51.6	1.02	56.0	52.4	1.07
	F	49.9	50.4	0.99	53.0	53.4	0.99
Bihar	M	N.A.	N.A.	N.A.	58.2	57.1	1.02
	F	N.A.	N.A.	N.A.	57.3	56.2	1.02
Gujarat	M	53.6	51.6	1.04	54.7	59.4	0.92
	F	55.3	53.2	1.04	61.8	65.4	0.95
Haryana	M	57.1	60.3	0.95	62.2	66.3	0.94
	F	52.1	57.3	0.90	61.3	65.5	0.94
Himachal Pradesh	M	60.0	58.1	1.03	63.0	58.9	1.07
	F	57.9	54.9	1.05	65.6	70.9	0.93
Jammu & Kashmir	M	58.2	58.1	1.00	64.3	62.3	1.03
	F	54.7	55.2	0.99	64.2	66.2	0.97
Karnataka	M	57.6	56.2	1.02	62.5	63.2	0.99
	F	58.0	56.6	1.02	66.5	67.4	0.99
Kerala	M	66.8	63.5	1.05	68.0	67.3	1.01
	F	67.2	67.6	1.00	73.4	75.4	0.97

TABLE 8 (*Concld.*)

State	M/F	1978			1988		
		Est.	SRS	Ratio	Est.	SRS	Ratio
Madhya Pradesh	M	52.5	49.4	1.06	54.8	53.6	1.02
	F	50.1	48.7	1.03	53.2	55.1	0.97
Maharashtra	M	59.5	55.6	1.07	61.7	63.6	0.97
	F	61.9	57.1	1.08	66.2	67.1	0.99
Orissa	M	52.6	50.0	1.05	57.8	56.2	1.03
	F	52.4	48.4	1.08	58.3	57.6	1.01
Punjab	M	61.7	60.9	1.03	64.4	64.3	1.00
	F	62.0	60.2	1.03	67.4	67.0	1.01
Rajasthan	M	50.4	51.0	0.99	53.9	55.6	0.97
	F	49.6	53.0	1.06	53.5	54.6	0.98
Tamil Nadu	M	56.3	53.5	1.05	62.6	59.5	1.05
	F	56.5	53.4	1.06	64.4	61.4	1.04
Uttar Pradesh	M	49.8	48.5	1.03	57.0	54.3	1.05
	F	38.7	43.8	0.88	55.3	53.2	1.04
West Bengal	M	N.A.	N.A.	N.A.	62.7	59.9	1.05
	F	N.A.	N.A.	N.A.	64.9	62.6	1.04
INDIA	M	54.4	52.5	1.04	59.6	58.3	1.02
	F	53.2	52.1	1.02	61.0	59.3	1.03

TABLE 10 : EXPECTATION OF LIFE USING GUNASEKARAN, PALMORE AND GARDNER METHOD

State	M/F	1978		1988	
		Est. 1	Est. 2	Est. 1	Est. 2
Andhra Pradesh	M	52.8	55.1	59.3	59.9
	F	54.5	58.3	61.7	64.3
Assam	M	57.4*	59.2*	58.1*	58.5*
	F	58.4*	57.2*	50.8*	47.8*
Bihar	M	N.A.	N.A.	56.6	55.3
	F	N.A.	N.A.	51.4	49.9
Guiarat	M	51.8	55.0	60.0	60.4
	F	44.8	54.9	59.6	59.2
Haryana	M	61.1*	57.9	61.2*	62.0
	F	53.1	49.7	56.8	62.6
Himachal Pradesh	M	61.6*	65.9*	61.7*	64.2*
	F	64.7*	57.4	63.3*	67.9
Jammu & Kashmir	M	62.8*	62.9*	61.1*	63.6*
	F	58.6	56.9	63.9	66.8
Karnataka	M	58.4	57.1	60.6	62.4
	F	57.8	52.1	60.6	62.6
Kerala	M	64.5	65.0*	66.5	65.9*
	F	67.3	65.8	73.2	72.9
Madhya Pradesh	M	50.3	55.7*	54.8	57.0*
	F	33.3	44.7*	51.8	54.2*
Maharashtra	M	60.1*	59.2	61.9*	64.0
	F	56.8	53.7	63.3	63.5

TABLE 10 (*Concld.*)

State	M/F	1978		1988	
		Est. 1	Est. 2	Est. 1	Est. 2
Orissa	M	53.6*	53.9	55.5*	57.9
	F	56.5*	57.8*	56.2*	57.3*
Punjab	M	55.5*	59.6*	56.1*	58.0
	F	50.7	58.5	58.5	63.5
Rajasthan	M	53.1	54.5	57.3	57.9
	F	43.7	45.0	53.4	52.8
Tamil Nadu	M	54.1	54.9	60.0	60.1
	F	55.4	57.5	60.0	61.2
Uttar Pradesh	M	52.1*	54.2	53.7*	56.7
	F	37.7	45.5	47.0	49.8
West Bengal	M	N.A.	N.A.	60.2	60.7
	F	N.A.	N.A.	61.3	59.8
INDIA	M	55.3	57.1*	58.1	59.0*
	F	52.4	55.0*	55.5	56.2*

*Represent sex-wise expectation of life at birth, ten years apart the differences of which is either too low, too large or decreasing.

Est. 1—Based on 0—4.

Est. 2—Based on 5—14.

TABLE 12 : EXPECTATION OF LIFE AT BIRTH USING RELE-PALMORE METHOD

State	M/F	1978			1988		
		Est.	SRS	Ratio	Est.	SRS	Ratio
Andhra Pradesh	M	56.2	52.2	1.08	59.7	62.2	0.96
	F	59.5	54.2	1.10	63.7	65.4	0.97
Assam	M	61.7	51.6	1.20	62.0	52.4	1.18
	F	57.0	50.4	1.13	53.0	53.4	0.99
Bihar	M	N.A.	N.A.	N.A.	57.6	57.1	1.01
	F	N.A.	N.A.	N.A.	54.0	56.2	0.96
Gujarat	M	54.0	51.6	1.05	60.3	59.4	1.02
	F	56.3	53.2	1.06	62.0	65.4	0.95
Haryana	M	61.4	60.3	1.02	64.1	66.3	0.97
	F	55.1	57.3	0.96	62.0	65.5	0.95
Himachal Pradesh	M	67.2*	58.1	1.16	65.9*	58.9	1.12
	F	60.7	54.9	1.11	64.8	70.9	0.91
Jammu & Kashmir	M	64.4*	58.1	1.11	65.2*	62.3	1.05
	F	55.7	55.2	1.01	65.5	66.2	0.98
Karnataka	M	59.2	56.2	1.05	63.1	63.2	1.00
	F	57.2	56.6	1.01	63.0	67.4	0.93
Kerala	M	62.1*	63.5	0.98	63.7*	67.3	0.95
	F	63.0	67.6	0.93	71.1	75.4	0.95

TABLE 12—*Concld.*

State	M/F	1978			1988		
		Est.	SRS	Ratio	Est.	SRS	Ratio
Madhya Pradesh	M	57.3	49.4	1.16	60.2	53.6	1.12
	F	49.3	48.7	1.01	57.6	55.1	1.05
Maharashtra	M	59.7	55.6	1.07	63.5	63.6	1.00
	F	56.2	57.1	0.98	64.3	67.1	0.96
Orissa	M	52.5	50.0	1.05	57.2	56.2	1.02
	F	53.9*	48.4	1.11	55.1*	57.6	0.96
Punjab	M	63.3	60.9	1.04	56.8	64.3	0.88
	F	62.3*	60.2	1.03	63.2*	67.0	0.94
Rajasthan	M	60.4*	51.0	1.18	61.5*	55.6	1.11
	F	57.7	53.0	1.09	62.1	54.6	1.14
Tamil Nadu	M	53.6	53.5	1.00	57.4	59.5	0.96
	F	53.2	53.4	1.00	56.9	61.4	0.93
Uttar Pradesh	M	59.5*	48.5	1.23	58.6*	54.3	1.08
	F	54.3*	43.8*	1.24	55.6*	53.2	1.05
West Bengal	M	N.A.	N.A.	N.A.	58.1	59.9	0.97
	F	N.A.	N.A.	N.A.	58.6	62.6	0.94
INDIA	M	58.3*	52.5	1.11	59.9*	58.3	1.03
	F	57.4	52.1	1.10	59.6	59.3	1.01

*Indicates figures ten years apart the difference of which are either too small or decreasing.

ANNEXE-IV

LIST OF SOFTWARE FOR THE PC USED IN THE TRAINING WORKSHOP

1. MORTPAK-LITE . .	Mortality, Life Tables and other Methods.
2. EASWESPOP-FERTILITY	Fertility Estimation Methods including P/F Ratio Method, Parity Increment Method, Rele's Method, Palmore Regression and Own-Children Methods.
3. FIV FIV-SIN SIN . .	Projections.

MGIPF—908 RGI/91—22-1-93—750