## 9·5·5. Assumptions, Description and Construction of Life Tables.

***Assumptions.*** The following are a few simplified assumptions which are used in the construction of the life tables.

(*i*) The cohort is closed for emigration or immigration. In other words, ***there is no change in the census except the losses due to deaths.***

(*ii*) Individuals die at each age according to pre-determined schedule which is fixed and does not change.

(*iii*) The cohort originates from some standard number of births, say 10,000 or 1,00,000 which is called the *radix* of the table.

(*iv*) The deaths are distributed uniformly over the period $(x, x+1)$ for each $x$ (except for first few years). In other words, deaths are uniformly distributed between one birthday and the next.

***Description of a Life Table.*** A typical life table has generally the following columns :

TABLE 9·11 : COLUMNS OF A LIFE TABLE

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| $x$ | $l_x$ | $d_x$ | $q_x$ | $p_x$ | $m_x$ | $\mu_x$ | $L_x$ | $T_x$ | $e_x^0$ | $e_x$ |

The various symbols entering in this table have already been defined in the preceding sections. Here we shall very briefly outline the various steps required for completing the table, starting with the second column. Of course, these relations have been obtained under the assumptions given above. For $x = 0, 1, 2, \ldots$ , we have

1. $d_x = l_x - l_{x+1}$  2. $q_x = \dfrac{d_x}{l_x}$  3. $p_x = 1 - q_x = \dfrac{l_{x+1}}{l_x}$

4. $m_x = \dfrac{2q_x}{2 - q_x}$  5. $\mu_{x+(1/2)} = m_x$  6. $L_x = l_x - \frac{1}{2}d_x = \frac{1}{2}(l_x + l_{x+1})$

7. $T_x = L_x + L_{x+1} + L_{x+2} + \ldots \Rightarrow T_{x+1} = T_x - L_x$  8. $e_x^0 = \dfrac{T_x}{l_x}$  9. $e_x = e_x^0 - \dfrac{1}{2}$

***Remark.*** The columns (5), (6) and (7) do not occur in all the life tables. However, the remaining columns are a must in any life table.

***Construction of Life Table.*** It will be seen, as discussed below, that the complete life table can be constructed if we can compute the quantities $q_x$ (or $p_x$) for all $x > 0$. The only other data which is needed is the *radix* $l_0$. The $q_x$ column is thus called the *pivotal column* of the life table. Starting with radix $l_0$ and $q_x$, $(x = 0, 1, 2, \ldots)$, we have

$$d_0 = l_0\, q_0 \Rightarrow l_1 = l_0 - d_0 \;;\quad d_1 = l_1\, q_1 \quad \text{or} \quad l_2 = l_1 - d_1$$

and so on. Form these values of $l_x$, $(x = 0, 1, 2, \ldots)$ the columns $L_x$, $T_x$ and $e_x^0$ of the table can now be completed by using the relations : $L_x = \frac{1}{2}(l_x + l_{x+1})$, $T_x = \sum_{i=x}^{\infty} L_i$, $e_x^0 = (T_x / l_x)$.

***Remarks* 1.** We have seen above that the complete life table can be constructed if we know the values of $l_0$ and $q_x$ $(x = 0, 1, 2, \ldots)$. The values of $q_x$ are obtained from (9·54), where the corresponding values $m_x = d_x / L_x$ are computed on the basis of census records and death registration data. It should be borne in mind that the construction of the life tables from the death registers as outlined above will yield reliable results only if the population has been stationary over a period at least equal to the age of the oldest survivor.

**2.** For reference, we reproduce in Tables 9·10 and 9·11, the All India Life Tables of Males and Females separately for the decade 1961— 1970, as prepared by Registrar-General of India. It may be observed that in these tables $L_x \neq \frac{1}{2}(l_x + l_{x+1})$ for initial values of $x$, since the assumption that deaths are uniformly distributed over the years is not satisfied for $x = 0, 1, 2, 3$. The values in the tables have been obtained by a more complicated formula.

TABLE 9·12 : LIFE TABLES INDIA, MALES 1961–1970

| *Age* | *Number living at age x* | *Survival ratio* | *Mortality rate* | *Number living between ages x and x + 1* | *Number living above age x* | *Expectation of life* |
|---|---|---|---|---|---|---|
| $x$ | $l_x$ | $p_x$ | $q_x$ | $L_x$ | $T_x$ | $e_x^0$ |
| *1* | *2* | *3* | *4* | *5* | *6* | *7* |
| 0 | 100000 | 0.86500 | 0.13500 | 89175 | 4707539 | 47.1 |
| 1 | 86500 | 0.94944 | 0.04056 | 84430 | 4617664 | 53.3 |
| 2 | 82992 | 0.98744 | 0.01056 | 82440 | 4533234 | 54.6 |
| 3 | 81950 | 0.99315 | 0.00685 | 81658 | 4450794 | 54.3 |
| 4 | 81388 | 0.99422 | 0.00578 | 81149 | 4369136 | 53.7 |
| 5 | 80918 | 0.99509 | 0.00491 | 80720 | 4287987 | 53.0 |
| 6 | 80521 | 0.99577 | 0.00423 | 80351 | 4207267 | 52.3 |
| 7 | 80181 | 0.99627 | 0.00373 | 80032 | 4126916 | 51.5 |
| 8 | 79882 | 0.99659 | 0.00341 | 79746 | 4046884 | 50.7 |
| 9 | 79609 | 0.99672 | 0.00328 | 79479 | 3967138 | 49.8 |
| 10 | 79348 | 0.99698 | 0.00302 | 79229 | 3887659 | 49.0 |
| 11 | 79109 | 0.99736 | 0.00264 | 79004 | 3808430 | 48.1 |
| 12 | 78900 | 0.99755 | 0.00245 | 78803 | 3729426 | 47.3 |
| 13 | 78706 | 0.99756 | 0.00244 | 78611 | 3650623 | 46.4 |
| 14 | 78514 | 0.99739 | 0.00260 | 78411 | 3572012 | 45.5 |
| 15 | 78309 | 0.99724 | 0.00276 | 78201 | 3493601 | 44.6 |
| 16 | 78092 | 0.99722 | 0.00278 | 77984 | 3415400 | 43.7 |
| 17 | 77875 | 0.99715 | 0.00258 | 77764 | 3337416 | 42.9 |
| 18 | 77653 | 0.99703 | 0.00297 | 77538 | 3259652 | 42.0 |
| 19 | 77422 | 0.99688 | 0.00312 | 77301 | 3112114 | 41.1 |
| 20 | 77181 | 0.99686 | 0.00314 | 77060 | 3104813 | 40.2 |
| 21 | 76938 | 0.99676 | 0.00324 | 76813 | 3027753 | 39.4 |
| 22 | 76689 | 0.99667 | 0.00333 | 76561 | 2950940 | 38.5 |
| 23 | 76433 | 0.99627 | 0.00373 | 76065 | 2874379 | 37.6 |
| 24 | 76148 | 0.99566 | 0.00434 | 75983 | 2708314 | 36.7 |
| 25 | 75818 | 0.99507 | 0.00493 | 75632 | 2722331 | 35.9 |
| 26 | 75445 | 0.99462 | 0.00538 | 75242 | 2646699 | 35.1 |
| 27 | 75039 | 0.99414 | 0.00586 | 74820 | 2571457 | 34.3 |
| 28 | 74599 | 0.99364 | 0.00639 | 74463 | 2496637 | 33.5 |
| 29 | 74125 | 0.99311 | 0.00689 | 73871 | 2422274 | 32.7 |
| 30 | 73615 | 0.99307 | 0.00693 | 73360 | 2348403 | 31.9 |
| 31 | 73105 | 0.99225 | 0.00775 | 72822 | 2275043 | 31.1 |
| 32 | 72538 | 0.99149 | 0.00851 | 72230 | 2202221 | 30.4 |
| 33 | 71921 | 0.99080 | 0.00920 | 71591 | 2129991 | 29.6 |
| 34 | 71260 | 0.99017 | 0.00983 | 70910 | 2058400 | 28.9 |
| 35 | 70559 | 0.98949 | 0.01051 | 70189 | 1987490 | 28.2 |
| 36 | 69818 | 0.98874 | 0.01126 | 69425 | 1917301 | 27.5 |
| 37 | 69032 | 0.98812 | 0.01188 | 68622 | 1847876 | 26.8 |
| 38 | 68212 | 0.98755 | 0.01245 | 67787 | 1779254 | 26.1 |
| 39 | 67362 | 0.98705 | 0.01295 | 66926 | 1711467 | 25.4 |

**9·5·6. Uses of Life Tables.** Although the basic objective of life tables is to give a clear picture of the age distribution of mortality in a given population group, it has been used widely in a large number of spheres. Today life table is widely accepted as important basic material in demographic and public health studies. In the words of **William Farr**, life table is the 'Biometer' of the population. We enumerate below some of important *applications* of life tables.

1. ***For Use by Actuaries in Insurance.*** Life tables are indispensable for the solution of all questions concerning the duration of human life. These tables, based on the scientific use of statistical methods, are the key stone or the pivot on which the whole science of life assurance hinges. Life tables form the basis for determining the rates of premiums to be paid by persons of different age groups, for various amount of life assurance. Life tables provide the actuarial science with a sound foundation, converting the insurance business from a mere gambling in human lives to the ability to offer well calculated safeguard in the event of death.

2. ***For Population Projections.*** Life tables are used by demographers to devise measures such as '*Net Reproduction Rate*' to study the rate of growth of population . They have also been used in preparation of population projections by age and sex, *i.e.*, in estimating what the size of the population will be at some future date.

3. ***For Comparison of Different Populations.*** Life tables for two or more different groups of population may be used for the relative comparison of various measures of mortality such as death rate, expectation of life at various ages, etc. Of particular interest is the comparison of $e_x^0$, the average longevity for members of a population.

4. Life tables are as well used by the government and the private establishments for determining the rates of retirement benefits to be given to its employees or for formulating various programmes for retired persons.

5. Since a life table depicts the distribution of the people according to age and sex, it is extremely useful in planning in respect of education and for predicting the school going population in connection with school building programmes.

6. Life tables are also used :

(*i*) For making policies and programmes relating to public health, by the government and public administration.

(*ii*) To evaluate the impact of family welfare programmes on the population growth.

(*iii*) For estimating the probable number of future widows and orphans in a community, and

(*iv*) For computing the approximate size of future labour force and military forces, etc.

***Example 9·4.*** *In the usual notations, prove that*

$$(i)\ \frac{dL_x}{dx} = -d_x, \quad (ii)\ \frac{dT_x}{dx} = -l_x, \text{ and } iii)\ \frac{d}{dx}\left(\overset{0}{e}_x\right) = \left(-1 + \mu_x \overset{0}{e}_x\right)$$

***Solution.*** By *def.*, we have

$$L_x = \int_0^1 l_{x+t}\, dt$$

**Example 9·6.** *Complete the life table of the population of a certain types of insects, x being the age in days and* $l_x = 1{,}000$ *for* $x = 0$ :

| $x$... | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| $q_x$... | 0·120 | 0·005 | 0·010 | 0·050 | 0·100 | 0·500 | 0·800 | 0·900 | 0·950 |

**Solution.** Since we are given the values of $q_x$, in order to complete the life table, first of all we shall find the values of $l_x$, $(x = 0, 1, 2, \ldots, 8)$ by using the relations :

$$q_x = \frac{d_x}{l_x} \quad \text{and} \quad l_{x+1} = l_x - d_x$$

We are given $l_0 = 1{,}000$

$\therefore\ d_0 = l_0 q_0 = 1000 \times 0·12 = 120·0$

$l_1 = l_0 - d_0 = 1000 - 120 = 880$

$d_1 = l_1 q_1 = 880 \times 0·005 = 4·0$

$l_2 = l_1 - d_1 = 880 - 4 = 876$

$d_2 = l_2 q_2$, $l_3 = l_2 - d_2$ and so on.

The values of $l_x$ and $d_x$, $(x = 0, 1, 2, \ldots 8)$ obtained on using (*) repeatedly are given in the *Table 9·13.*

TABLE 9·14

| $x$ | $q_x$ | $l_x$ | $d_x = l_x q_x$ |
|---|---|---|---|
| 0 | 0·120 | 1000 | $100 \times 0·120 = 120$ |
| 1 | 0·005 | $100 - 120 = 880$ | $880 \times 0·005 = 4·4 \simeq 4$ |
| 2 | 0·010 | $880 - 4 = 876$ | $876 \times 0·010 = 8·76 \simeq 9$ |
| 3 | 0·050 | $876 - 9 = 867$ | $867 \times 0·050 = 43·35 \simeq 43$ |
| 4 | 0·100 | $867 - 43 = 824$ | $824 \times 0·100 = 82·4 \simeq 82$ |
| 5 | 0·500 | $824 - 82 = 742$ | $742 \times 0·500 = 371·0$ |
| 6 | 0·800 | $742 - 371 = 371$ | $371 \times 0·800 = 296·8 \simeq 297$ |
| 7 | 0·900 | $371 - 297 = 74$ | $74 \times 0·900 = 66·6 \simeq 67$ |
| 8 | 0·950 | $74 - 67 = 7$ | $7 \times 0·950 = 6·65 \simeq 7$ |

The remaining columns of the life table, *viz.*, $L_x$, $T_x$ and $e_x^0$ can now be completed as discussed in *Example 9·4.*

**Example 9·7.** *Fill in the blanks of the following table which are marked with question marks :*

| *Age, x* : | $l_x$ | $d_x$ | $q_x$ | $p_x$ | $L_x$ | $e_x^0$ |
|---|---|---|---|---|---|---|
| 20 | 6,93,435 | ? | ? | ? | ? | 35,081,126 |
| 21 | 6,90,673 | — | — | — | — | ? |

**Solution.** Taking age 20 $x$, *i.e.*, age 21 as $x + 1$, in the usual notations, we get

$d_{20} = l_{20} - l_{21} = 693435 - 690673 = 2762$

$$q_{20} = \frac{d_{20}}{l_{20}} = \frac{2762}{693435} = 0·00398$$

$p_{20} = 1 - q_{20} = 1 - 0·00398 = 0·99602$

$$L_{20} = \frac{l_{20} + l_{21}}{2} = \frac{693435 + 690673}{2} = 692054$$

$T_{21} = T_{20} - L_{20} = 35081126 - 692054 = 34389072$

$$e_{20}^0 = \frac{T_{20}}{l_{20}} = \frac{35081126}{693435} = 50·59$$

$$e_{21}^0 = \frac{T_{21}}{l_{21}} = \frac{34389072}{690673} = 49·79$$

**Example 9·8.** *Fill in the blanks in a portion of life table given below:*

| *Age (in years)* | $l_x$ | $d_x$ | $p_x$ | $q_x$ | $L_x$ | $T_x$ | $e_x^0$ |
|---|---|---|---|---|---|---|---|
| 4 | 95,000 | 500 | ? | ? | ? | 4,850,300 | ? |
| 5 | ? | 400 | ? | ? | ? | ? | ? |

***Solution.*** In the usual notations, we have

$l_5 = l_4 - d_4 = 95000 - 500 = 94500$

$p_4 = \frac{l_5}{l_4} = \frac{94500}{95000} = 0{\cdot}9947$

$q_4 = 1 - p_4 = 1 - 0{\cdot}9947 = 0{\cdot}0053$

$l_6 = l_5 - d_5 = 94500 - 400 = 94100$

$p_5 = \frac{l_6}{l_5} = \frac{94100}{94500} = 0{\cdot}9958$

$q_5 = 1 - p_5 = 1 - 0{\cdot}9958 = 0{\cdot}0042$

$q_5 = 1 - p_5 = 1 - 0{\cdot}9958 = 0{\cdot}0042$

$L_4 = \frac{l_4 + l_5}{2} = \frac{95000 + 94500}{2} = 94750$

$L_5 = \frac{l_4 + l_5}{2} = \frac{94500 + 94100}{2} = 94300$

$e_4^0 = \frac{T_4}{l_4} = \frac{4850300}{95000} = 51{\cdot}06$

$T_5 = T_4 - L_4 = 4850300 - 94750 = 4755550$

$e_5^0 = \frac{T_5}{l_5} = \frac{4755550}{94500} = 50{\cdot}32.$

***Example 9·9.*** *Given that the complete expectation of life at ages 30 and 31 for a particular group are respectively 21·39 and 20·91 years and that the number living at age 30 is 41,176; find (i) the number that attains the age 31 and (ii) the number that will die without attaining the age 31.*

***Solution.*** (*i*) In the usual notations we want the value of $l_{31}$ and we are given :

$$\overset{0}{e}_{30} = 21{\cdot}39,\ \overset{0}{e}_{31} = 20{\cdot}90 \quad \text{and} \quad l_{30} = 41176$$

$$\therefore \quad e_{30} = \overset{0}{e}_{30} - \frac{1}{2} = 21{\cdot}39 - 0{\cdot}5 = 20{\cdot}89\ ; \quad \text{and} \quad e_{31} = \overset{0}{e}_{31} - \frac{1}{2} = 20{\cdot}91 - 0{\cdot}5 = 20{\cdot}41$$

Here we shall use the formulae :

$$p_x = \frac{l_{x+1}}{l_x} = \frac{e_x}{1 + e_{x+1}} \qquad \ldots(*)$$

Taking $x = 30$, we get

$$\frac{l_{31}}{l_{30}} = \frac{e_{30}}{1+e_{31}} \Rightarrow l_{31} = \frac{l_{30}e_{30}}{1+e_{31}} = \frac{41176 \times 20{\cdot}89}{20{\cdot}41} = 40176$$

(*iii*) The number of persons who die without attaining the age 31 is equal to the numbers of persons dying between the age period 30 and 31 and is given by :

$$d_{30} = l_{30} - l_{31} = 41176 - 40176 = 1000.$$

***Example 9·10.*** *The number of persons dying at age 75 is 476 and the complete expectation of life at 75 and 76 years are 3·92 and 3·66 years. Find the numbers living at ages 75 and 76.*

***Solution.*** In the usual notations, we are given

$$\overset{0}{e}_{75} = 3{\cdot}92,\ \overset{0}{e}_{75} = 3{\cdot}66,\ d_{75} = 476. \text{ We want } l_{75} \text{ and } l_{76}$$

We have

$$e_{75} = \overset{0}{e}_{75} - 0{\cdot}50 = 3{\cdot}42\ ; \quad e_{7{\cdot}6} = \overset{0}{e}_{7{\cdot}6} - 0{\cdot}50 = 3{\cdot}16$$

As in the above example, we get from (*)

$$l_{76} = \frac{l_{75}e_{75}}{1+e_{76}} = \frac{3{\cdot}42}{4{\cdot}16} l_{75} = 0{\cdot}8221\, l_{75}$$

Also $$d_x = l_x - l_{x+1} \Rightarrow d_{75} = l_{75} - l_{76} = 476 \text{ (given)}$$

$$\therefore \quad l_{75} - 0{\cdot}8221\, l_{75} = 476 \Rightarrow (1 - 0{\cdot}8221)\, l_{75} = 476$$

$$\Rightarrow \quad l_{75} = \frac{476}{0{\cdot}1779} = 2675{\cdot}66 \simeq 2676$$

and $$l_{76} = l_{75} - d_{75} = 2676 - 476 = 2200.$$

death rate is on the decline and the percentage of population in 60 plus age group is on the increase.

## LIFE TABLE

Life table is a mathematical sample which gives a view of death in a country and is the basis for measuring the average life expectancy in a society. It tells about the probability of a person dying at a certain age, or living upto a definite age. According to **Bogue**, "The life table is a mathematical model that portrays mortality condition at a particular time among a population and provides a basis for measuring longevity.It is based on age specific mortality rates observed for a population for a particular year." **Barclay** defines it in these words: "The life table is a life history of a hypothetical group or cohort of people, as it is diminished gradually by death. The record begins at the birth of each member and continues until all died." Thus a life table is a mathematical device which shows the life span of persons upto a particular age or their probable date of death relates to a cohort of people born at the same time until they die.

A life table can be constructed for a country and an area on the basis of sex, occupation, race, etc.

### Types of Life Tables

Life tables are of two types: Cohort or Generation Life Table, and Period Life Table. The Cohort or Generation Life Table "summarises the age specific mortality experience of a given birth cohort (a group of persons all born at the same time) for its life and thus extends over many calender years." On the other hand, the "Period Life Table summarises the age specific mortality conditions pertaining to a given or other short time period."

### Assumptions of Life Table

A life table is based on the following assumptions:

1. A hypothetical cohort of life table usually comprises of 1,000 or 10,000 or 1,00,000 births.
2. The deaths are equally distributed throughout the year.
3. The cohort of people diminish gradually by death only.
4. The cohort is closed to the in-migration and out-migration.
5. The death rate is related to a pre-determined age specific death rate.
6. The cohort of persons die at a fixed age which does not change.
7. There is no change in death rates overtime.
8. The cohort of life tables are generally constructed separately for males and females.

### Methods of Constructing Life Table

Life tables are constructed on the basis of a single cross-sectional time data for a generation. There is also a longitudinal life table method which takes a real cohort of persons that start life at a specific age interval and follow it throughout life until they die.

Further, a *complete life table* may be constructed on the basis of single years of ages. An *abridged life table* can also be constructed wherein ages are grouped in 5 or 10 years of interval, taking the intial year as 0-1.

The hypothetical cohort of abridged life table is shown in Table 3.3 where column (1) indicates the age interval.

**TABLE 3.3**
**Hypothetical Cohort of Abridged Life Table**

| *Age Interval* | *Probability of Death* | *Per 1,00,000 Live Birth* | |
|---|---|---|---|
| | | *No. of Persons Surviving at the Exact Age* | *No. of Deaths During the Age Interval* |
| *x* to *x* + *n* | *ax* | *fx* | *dx* |
| (1) | (2) | (3) | (4) |
| 0—1 | .0250 | 1,00,000 | 2500 |
| 1—5 | .0051 | 97,500 | 500 |
| 5—10 | .0031 | 97,000 | 300 |
| 10—15 | .0026 | 96,700 | 250 |
| 15—20 | .0062 | 96,450 | 600 |
| 20—25 | .0083 | 95,850 | 800 |
| 25—30 | .0079 | 95,050 | 750 |
| 30—35 | .0087 | 94,300 | 825 |
| 35—40 | .0013 | 93,475 | 1200 |
| 40—45 | .0217 | 92,275 | 2000 |
| 45—50 | .0332 | 90,275 | 3000 |
| 50—55 | .0579 | 87,275 | 5050 |
| 55—60 | .0857 | 82,225 | 7050 |
| 60—65 | .0133 | 75,175 | 10000 |
| 65—70 | .0460 | 65,175 | 13000 |
| 70—75 | .2251 | 62,175 | 14000 |
| 75—80 | .3114 | 48,175 | 15000 |
| 80 and over | .3919 | 33,175 | 13000 |

From the above example it can be seen that column 1 indicates age interval $x$ to $x + 1$ ....... $x + n$. During the period of life between the age $x$ to $x + 1$ out of 100,000 live births at the beginning of the age interval $x$ to $x + 1$ (col. 3), 2500 deaths occur before they complete one year (col. 4). This shows that the number of deaths in the age group $x$ to $x + 1$ is 25 per 1000 children and the probability of dying per cohort is .0250 (Col. 2). Similarly, if we examine the time period of life between the age $x + 1$ to $x + 5$, we find that in this age group, the number of persons surviving will be 97,500 (100,000 – 2500), out of which, 500 deaths occur during this age group and the probability of death per cohort will be .0051. Similarly, hypothetical life table for other age groups can be calculated. Table 3.4 depicts a hypothetical complete life table for India during 1971-80.

**TABLE 3.4**
**Hypothetical Complete Life Table for India (1971–80)**

| Age *x* to *x+n* | *dx* | *fx* *fx – dx* (3– 2) | *qx* *dx/fx* (2/3) | *px* 1 – *qx* (1– 4) | *Lx* (*fx*0 + *fx*1)/2 | *Tx* *Tx*1 = T×*x*0 – L×*x*0 | *ex* *Tx/Fx* |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0. | 13000 | 100000 | 0.13000 | 0.87000 | 93500 | 4930250 | 49.3 |
| 1. | 1300 | 87000 | 0.01494 | 0.98506 | 86350 | 4836750 | 55.6 |
| 2. | 1200 | 85700 | 0.01400 | 0.98600 | 85100 | 4750400 | 55.4 |
| 3. | 100 | 84500 | 0.00118 | 0.99882 | 84450 | 4665300 | 55.2 |
| 4. | 800 | 84400 | 0.00948 | 0.99052 | 84000 | 4580850 | 54.3 |
| 5. | 500 | 83600 | 0.00598 | 0.99402 | 83350 | 4496850 | 53.8 |
| 6. | 300 | 83100 | 0.00361 | 0.99639 | 82950 | 4413500 | 53.1 |
| 7. | 200 | 82800 | 0.00242 | 0.99758 | 82700 | 4330550 | 52.3 |
| 8. | 100 | 82600 | 0.00121 | 0.99879 | 82550 | 4247850 | 51.4 |
| 9. | 70 | 82500 | 0.00085 | 0.99915 | 82465 | 4165300 | 50.5 |
| 10. | 65 | 82430 | 0.00079 | 0.99921 | 82398 | 4082835 | 49.5 |
| 11. | 60 | 82365 | 0.00073 | 0.99927 | 82335 | 4000438 | 48.6 |
| 12. | 80 | 82305 | 0.00097 | 0.99903 | 82265 | 3918103 | 47.6 |
| 13. | 100 | 82225 | 0.00122 | 0.99878 | 82175 | 3835838 | 46.7 |
| 14. | 200 | 82125 | 0.00244 | 0.99756 | 82025 | 3753663 | 45.7 |
| 15. | 210 | 81925 | 0.00256 | 0.99744 | 81820 | 3671638 | 44.8 |
| 16. | 215 | 81715 | 0.00263 | 0.99737 | 81608 | 3589818 | 43.9 |
| 17. | 220 | 81500 | 0.00270 | 0.99730 | 81390 | 3508210 | 43.0 |
| 18. | 225 | 81280 | 0.00277 | 0.99723 | 81168 | 3426820 | 42.2 |
| 19. | 230 | 81055 | 0.00284 | 0.99716 | 80940 | 3345653 | 41.3 |
| 20. | 225 | 80825 | 0.00278 | 0.99722 | 80713 | 3264713 | 40.4 |
| 21. | 230 | 80600 | 0.00285 | 0.99715 | 80485 | 3184000 | 39.5 |
| 22. | 235 | 80370 | 0.00292 | 0.99708 | 80253 | 3103515 | 38.6 |
| 23. | 240 | 80135 | 0.00299 | 0.99701 | 80015 | 3023263 | 37.7 |
| 24. | 245 | 79895 | 0.00307 | 0.99693 | 79773 | 2943248 | 36.8 |
| 25. | 260 | 79650 | 0.00326 | 0.99674 | 79520 | 2863475 | 36.0 |
| 26. | 275 | 79390 | 0.00346 | 0.99654 | 79253 | 2783955 | 35.1 |
| 27. | 285 | 79115 | 0.00360 | 0.99640 | 78973 | 2704703 | 34.2 |
| 28. | 295 | 78830 | 0.00374 | 0.99626 | 78683 | 2625730 | 33.3 |
| 29. | 320 | 78535 | 0.00407 | 0.99593 | 78375 | 2547048 | 32.4 |
| 30. | 350 | 78215 | 0.00447 | 0.99553 | 78040 | 2468673 | 31.6 |
| 31. | 400 | 77865 | 0.00514 | 0.99486 | 77665 | 2390633 | 30.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 75. | 1300 | 17050 | 0.07625 | 0.92375 | 16400 | 143525 | 8.4 |
| 76. | 1250 | 15750 | 0.07937 | 0.92063 | 15125 | 127125 | 8.1 |
| 77. | 1200 | 14500 | 0.08276 | 0.91724 | 13900 | 112000 | 7.7 |
| 78. | 1150 | 13300 | 0.08647 | 0.91353 | 12725 | 98100 | 7.4 |
| 79. | 1075 | 12150 | 0.08848 | 0.91152 | 11613 | 85375 | 7.0 |
| 80. | 1025 | 11075 | 0.09255 | 0.90745 | 10563 | 73763 | 6.7 |
| 81. | 950 | 10050 | 0.09453 | 0.90547 | 9575 | 63200 | 6.3 |
| 82. | 900 | 9100 | 0.09890 | 0.90110 | 8650 | 53625 | 5.9 |
| 83. | 850 | 8200 | 0.10366 | 0.89634 | 7775 | 44975 | 5.5 |
| 84. | 825 | 7350 | 0.11224 | 0.88776 | 6938 | 37200 | 5.1 |
| 85. | 800 | 6525 | 0.12261 | 0.87739 | 6125 | 30263 | 4.6 |
| 86. | 775 | 5725 | 0.13537 | 0.86463 | 5338 | 24138 | 4.2 |
| 87. | 750 | 4950 | 0.15152 | 0.84848 | 4575 | 18800 | 3.8 |
| 88. | 725 | 4200 | 0.17262 | 0.82738 | 3838 | 14225 | 3.4 |
| 89. | 675 | 3475 | 0.19424 | 0.80576 | 3138 | 10388 | 3.0 |
| 90. | 625 | 2800 | 0.22321 | 0.77679 | 2488 | 7250 | 2.6 |
| 91. | 525 | 2175 | 0.24138 | 0.75862 | 1913 | 4763 | 2.2 |
| 92. | 500 | 1650 | 0.30303 | 0.69697 | 1400 | 2850 | 1.7 |
| 93. | 450 | 1150 | 0.39130 | 0.60870 | 925 | 1450 | 1.3 |
| 94. | 350 | 700 | 0.50000 | 0.50000 | 525 | 525 | 0.8 |
| 95. | 350 | 350 | 1.00000 | 0.00000 | 175 | 0 | 0.0 |
| 96. | 200 | 0 | | | 0 | | |

The above life table provides the columnwise information which is generally provided and followed by all life tables.

Col. 1. $x$ = Specific Age
If the age at birth is $x$ then the age at one year is $x + 1$. Similarly the age at 15 years is $x + 15$.

Col. 2. $dx$ = Number of deaths, at any particular age, i.e., at the age $x$, 13000 deaths occur out of 1,00,000 births, then at age $x + 1$ : 87,000 persons will be alive. In this age, if 1300 deaths occur then at age $x + 2$ : 85700 persons will be alive.

Col. 3. $fx$ = The number of persons surviving at age $x$ to $x + n$ i.e., at the age $x + 1$ = 1,00,000 – 13,000 = 87,000

Col. 4. $qx$ = Probability of death per person in the specific age i.e., total deaths occurred. (Out of 1,00,000 = 13,000)
Probability = 13,000 ÷ 1,00,000 = 0.13
Similarly, at the age $x + 1$, 1300 persons died out of 87,000 live population then Probability = 1300 ÷ 87,000 = 0.01494.

Col. 5. $Px$ = 1 – Probability of surviving per individual person or $1 - qx$, i.e.; At age $x$, 1 – .13000 = .87000 and at age $x + 1$, 1– .01494 = .98506.

Col. 6. $Lx$ = Number of years lived by the cohort in the age $x$ to $x + n$ or

$fx$ of any two age groups ÷ 2.
Suppose,

$fx - 15 = 81925$ [col. : 3, row 15]
$fx - 16 = 81715$ [col. : 3, row 16]

$Lx = 163640 \div 2 = 81820$

Col. 7. $Tx$ = Total number of years lived by the cohort after exact age $x$. This can be found out from the reverse side of life table, i.e.,
At the age of 94 $Lx = 525$ and
at age 93 $Lx = 925$
then at age $x + 93$, total number of years lived by Cohort = 525 + 925 = 1450 and at age $x + 92$, it will be 525 + 925 + 1400 = 2850.

Col. 8. Ex = $Tx \div Fx$. This gives average life expectancy.

In short, the life table is based on the age of death period of a particular population. By studying this table, we can show the probability of death of any person of any particular age group. It is to be noted that every person of a particular age group does not die according to the estimate of the life table. The life table only shows a trend.

## Importance of Life Table

Life tables have been constructed by **Graunt**, **Reed** and **Merrell**, **Keyfitz**, **Greville** and other demographers for estimating population trends regarding death rates, average expectation of life, migration rates, etc. We detail below the uses of life tables:

1. Life table is used to project future population on the basis of the present death rate.

2. It helps in determining the average expectation of life based on age specific death rates.

3. The method of constructing a life table can be followed to estimate the cause of specific death rates, male and female death rates, etc.

4. The survival rates in a life table can be used to calculate the net migration rate on the basis of age distribution at 5 or 10 year interval.

5. Life tables can be used to compare population trends at national and international levels.

6. By constructing a life table based on the age at marriage, marriage patterns and changes in them can be estimated.

7. Instead of a single life table, multiple decrement life tables relating to cause specific death rate, male and female death rates, etc. can be constructed for analysing socio-economic data in a country.

8. Life tables are particularly used for formulating family planning programmes relating to infant mortality, maternal deaths, health programmes, etc. They can also be used for evaluating family planning programmes.

9. Now a days, life tables are used by life insurance companies in order to

estimate the average life expectancy of persons, separately for males and females. They help in determining the amount of premium to be paid by a person falling in a specific age group. Besides, if an insured person dies before the policy matures, the life table provides economic support to the insurance company without facing financial loss and it is able to give the insured amount to the legal heirs of the deceased.

## POPULATION PYRAMID

When the age structure of population is classified by sex in the form of a histogram, it is called age-sex pyramid. The base of the pyramid shows very low age starting from zero, it increases as we move upwards. The top of the pyramid shows the maximum age above 85 years. Population pyramids are of 5-year intervals.

On the left of the pyramid is shown the age of male population and on the right of the female population, thereby indicating the sexes. Pyramids are of two types: *One,* based on absolute numbers of population and the *second,* on the proportion of population. The former shows the size and composition of population of a country. The second type is used to compare the age-sex composition of two countries, on a single scale of which one is small and the other is big, such as India and Sri Lanka.

Figures 2.1 and 2.2 depict two different population pyramids.

Figure 2.1 reflects the condition of age-sex pyramid of developing countries like India while the second figure reflects the condition of age-sex pyramid of developed countries like the United States of America. Fig. 2.1 shows a very wide base, while it is of a rectangular shape in Fig. 2.2. This shows the distinct variation in the age structure of population of both developing and developed countries. In developing countries, there is a marked decline in the death rate because the population is becoming younger, while in developed countries, both birth and death rates stablise at a low level. During the first stage of demographic transition, the death rate is high due to high infant mortality rate and the existence of low economic development. But with economic development, the decrease in mortality rate becomes possible which ultimately increases the proportion of the younger population. The population pyramid becomes conic when we move upwards if other things remain constant. This happens due to decline in death rate.

### Views of Thomson and Lewis Regarding Population Pyramid

According to **Thomson** and **Lewis**, there are five types of population pyramids. All these different types of pyramids indicate the relation of population growth with economic development. In other words, the population pyramid reflects the condition of birth and death rates in different stages explained in the demographic transition theory.

**First,** we find in Fig. 2.3 a very wide base and slow slopes which indicate the demographic condition of those countries where both the birth rate and the death rate is on the decline and the percentage of population in 60 plus age group is on the increase.

## LIFE TABLE

Life table is a mathematical sample which gives a view of death in a country and is the basis for measuring the average life expectancy in a society. It tells about the probability of a person dying at a certain age, or living upto a definite age. According to **Bogue**, "The life table is a mathematical model that portrays mortality condition at a particular time among a population and provides a basis for measuring longevity.It is based on age specific mortality rates observed for a population for a particular year." **Barclay** defines it in these words: "The life table is a life history of a hypothetical group or cohort of people, as it is diminished gradually by death. The record begins at the birth of each member and continues until all died." Thus a life table is a mathematical device which shows the life span of persons upto a particular age or their probable date of death relates to a cohort of people born at the same time until they die.

A life table can be constructed for a country and an area on the basis of sex, occupation, race, etc.

### Types of Life Tables

Life tables are of two types: Cohort or Generation Life Table, and Period Life Table. The Cohort or Generation Life Table "summarises the age specific mortality experience of a given birth cohort (a group of persons all born at the same time) for its life and thus extends over many calender years." On the other hand, the "Period Life Table summarises the age specific mortality conditions pertaining to a given or other short time period."

### Assumptions of Life Table

A life table is based on the following assumptions:

1. A hypothetical cohort of life table usually comprises of 1,000 or 10,000 or 1,00,000 births.
2. The deaths are equally distributed throughout the year.
3. The cohort of people diminish gradually by death only.
4. The cohort is closed to the in-migration and out-migration.
5. The death rate is related to a pre-determined age specific death rate.
6. The cohort of persons die at a fixed age which does not change.
7. There is no change in death rates overtime.
8. The cohort of life tables are generally constructed separately for males and females.

### Methods of Constructing Life Table

Life tables are constructed on the basis of a single cross-sectional time data for a generation. There is also a longitudinal life table method which takes a real cohort of persons that start life at a specific age interval and follow it throughout life until they die.

Further, a *complete life table* may be constructed on the basis of single years of ages. An *abridged life table* can also be constructed wherein ages are grouped in 5 or 10 years of interval, taking the intial year as 0-1.

The hypothetical cohort of abridged life table is shown in Table 3.3 where column (1) indicates the age interval.

**TABLE 3.3**
**Hypothetical Cohort of Abridged Life Table**

| *Age Interval* | *Probability of Death* | *Per 1,00,000 Live Birth* | |
|---|---|---|---|
| | | *No. of Persons Surviving at the Exact Age* | *No. of Deaths During the Age Interval* |
| *x* to *x* + *n* | *ax* | *fx* | *dx* |
| (1) | (2) | (3) | (4) |
| 0—1 | .0250 | 1,00,000 | 2500 |
| 1—5 | .0051 | 97,500 | 500 |
| 5—10 | .0031 | 97,000 | 300 |
| 10—15 | .0026 | 96,700 | 250 |
| 15—20 | .0062 | 96,450 | 600 |
| 20—25 | .0083 | 95,850 | 800 |
| 25—30 | .0079 | 95,050 | 750 |
| 30—35 | .0087 | 94,300 | 825 |
| 35—40 | .0013 | 93,475 | 1200 |
| 40—45 | .0217 | 92,275 | 2000 |
| 45—50 | .0332 | 90,275 | 3000 |
| 50—55 | .0579 | 87,275 | 5050 |
| 55—60 | .0857 | 82,225 | 7050 |
| 60—65 | .0133 | 75,175 | 10000 |
| 65—70 | .0460 | 65,175 | 13000 |
| 70—75 | .2251 | 62,175 | 14000 |
| 75—80 | .3114 | 48,175 | 15000 |
| 80 and over | .3919 | 33,175 | 13000 |

From the above example it can be seen that column 1 indicates age interval *x* to *x* + 1 ....... *x* + *n*. During the period of life between the age *x* to *x* + 1 out of 100,000 live births at the beginning of the age interval *x* to *x* + 1 (col. 3), 2500 deaths occur before they complete one year (col. 4). This shows that the number of deaths in the age group *x* to *x* + 1 is 25 per 1000 children and the probability of dying per cohort is .0250 (Col. 2). Similarly, if we examine the time period of life between the age *x* + 1 to *x* + 5, we find that in this age group, the number of persons surviving will be 97,500 (100,000 – 2500), out of which, 500 deaths occur during this age group and the probability of death per cohort will be .0051. Similarly, hypothetical life table for other age groups can be calculated. Table 3.4 depicts a hypothetical complete life table for India during 1971-80.

**TABLE 3.4**
**Hypothetical Complete Life Table for India (1971–80)**

| Age *x* to *x+n* | *dx* | *fx* *fx – dx* (3– 2) | *qx* *dx/fx* (2/3) | *px* 1 – *qx* (1– 4) | *Lx* (*fx*0 + *fx*1)/2 | *Tx* *Tx*1 = *Tx*x0 – *Lx*x0 | *ex* *Tx/Fx* |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0. | 13000 | 100000 | 0.13000 | 0.87000 | 93500 | 4930250 | 49.3 |
| 1. | 1300 | 87000 | 0.01494 | 0.98506 | 86350 | 4836750 | 55.6 |
| 2. | 1200 | 85700 | 0.01400 | 0.98600 | 85100 | 4750400 | 55.4 |
| 3. | 100 | 84500 | 0.00118 | 0.99882 | 84450 | 4665300 | 55.2 |
| 4. | 800 | 84400 | 0.00948 | 0.99052 | 84000 | 4580850 | 54.3 |
| 5. | 500 | 83600 | 0.00598 | 0.99402 | 83350 | 4496850 | 53.8 |
| 6. | 300 | 83100 | 0.00361 | 0.99639 | 82950 | 4413500 | 53.1 |
| 7. | 200 | 82800 | 0.00242 | 0.99758 | 82700 | 4330550 | 52.3 |
| 8. | 100 | 82600 | 0.00121 | 0.99879 | 82550 | 4247850 | 51.4 |
| 9. | 70 | 82500 | 0.00085 | 0.99915 | 82465 | 4165300 | 50.5 |
| 10. | 65 | 82430 | 0.00079 | 0.99921 | 82398 | 4082835 | 49.5 |
| 11. | 60 | 82365 | 0.00073 | 0.99927 | 82335 | 4000438 | 48.6 |
| 12. | 80 | 82305 | 0.00097 | 0.99903 | 82265 | 3918103 | 47.6 |
| 13. | 100 | 82225 | 0.00122 | 0.99878 | 82175 | 3835838 | 46.7 |
| 14. | 200 | 82125 | 0.00244 | 0.99756 | 82025 | 3753663 | 45.7 |
| 15. | 210 | 81925 | 0.00256 | 0.99744 | 81820 | 3671638 | 44.8 |
| 16. | 215 | 81715 | 0.00263 | 0.99737 | 81608 | 3589818 | 43.9 |
| 17. | 220 | 81500 | 0.00270 | 0.99730 | 81390 | 3508210 | 43.0 |
| 18. | 225 | 81280 | 0.00277 | 0.99723 | 81168 | 3426820 | 42.2 |
| 19. | 230 | 81055 | 0.00284 | 0.99716 | 80940 | 3345653 | 41.3 |
| 20. | 225 | 80825 | 0.00278 | 0.99722 | 80713 | 3264713 | 40.4 |
| 21. | 230 | 80600 | 0.00285 | 0.99715 | 80485 | 3184000 | 39.5 |
| 22. | 235 | 80370 | 0.00292 | 0.99708 | 80253 | 3103515 | 38.6 |
| 23. | 240 | 80135 | 0.00299 | 0.99701 | 80015 | 3023263 | 37.7 |
| 24. | 245 | 79895 | 0.00307 | 0.99693 | 79773 | 2943248 | 36.8 |
| 25. | 260 | 79650 | 0.00326 | 0.99674 | 79520 | 2863475 | 36.0 |
| 26. | 275 | 79390 | 0.00346 | 0.99654 | 79253 | 2783955 | 35.1 |
| 27. | 285 | 79115 | 0.00360 | 0.99640 | 78973 | 2704703 | 34.2 |
| 28. | 295 | 78830 | 0.00374 | 0.99626 | 78683 | 2625730 | 33.3 |
| 29. | 320 | 78535 | 0.00407 | 0.99593 | 78375 | 2547048 | 32.4 |
| 30. | 350 | 78215 | 0.00447 | 0.99553 | 78040 | 2468673 | 31.6 |
| 31. | 400 | 77865 | 0.00514 | 0.99486 | 77665 | 2390633 | 30.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 75. | 1300 | 17050 | 0.07625 | 0.92375 | 16400 | 143525 | 8.4 |
| 76. | 1250 | 15750 | 0.07937 | 0.92063 | 15125 | 127125 | 8.1 |
| 77. | 1200 | 14500 | 0.08276 | 0.91724 | 13900 | 112000 | 7.7 |
| 78. | 1150 | 13300 | 0.08647 | 0.91353 | 12725 | 98100 | 7.4 |
| 79. | 1075 | 12150 | 0.08848 | 0.91152 | 11613 | 85375 | 7.0 |
| 80. | 1025 | 11075 | 0.09255 | 0.90745 | 10563 | 73763 | 6.7 |
| 81. | 950 | 10050 | 0.09453 | 0.90547 | 9575 | 63200 | 6.3 |
| 82. | 900 | 9100 | 0.09890 | 0.90110 | 8650 | 53625 | 5.9 |
| 83. | 850 | 8200 | 0.10366 | 0.89634 | 7775 | 44975 | 5.5 |
| 84. | 825 | 7350 | 0.11224 | 0.88776 | 6938 | 37200 | 5.1 |
| 85. | 800 | 6525 | 0.12261 | 0.87739 | 6125 | 30263 | 4.6 |
| 86. | 775 | 5725 | 0.13537 | 0.86463 | 5338 | 24138 | 4.2 |
| 87. | 750 | 4950 | 0.15152 | 0.84848 | 4575 | 18800 | 3.8 |
| 88. | 725 | 4200 | 0.17262 | 0.82738 | 3838 | 14225 | 3.4 |
| 89. | 675 | 3475 | 0.19424 | 0.80576 | 3138 | 10388 | 3.0 |
| 90. | 625 | 2800 | 0.22321 | 0.77679 | 2488 | 7250 | 2.6 |
| 91. | 525 | 2175 | 0.24138 | 0.75862 | 1913 | 4763 | 2.2 |
| 92. | 500 | 1650 | 0.30303 | 0.69697 | 1400 | 2850 | 1.7 |
| 93. | 450 | 1150 | 0.39130 | 0.60870 | 925 | 1450 | 1.3 |
| 94. | 350 | 700 | 0.50000 | 0.50000 | 525 | 525 | 0.8 |
| 95. | 350 | 350 | 1.00000 | 0.00000 | 175 | 0 | 0.0 |
| 96. | 200 | 0 | | | 0 | | |

The above life table provides the columnwise information which is generally provided and followed by all life tables.

Col. 1. $x$ = Specific Age
If the age at birth is $x$ then the age at one year is $x + 1$. Similarly the age at 15 years is $x + 15$.

Col. 2. $dx$ = Number of deaths, at any particular age, i.e., at the age $x$, 13000 deaths occur out of 1,00,000 births, then at age $x + 1$ : 87,000 persons will be alive. In this age, if 1300 deaths occur then at age $x + 2$ : 85700 persons will be alive.

Col. 3. $fx$ = The number of persons surviving at age $x$ to $x + n$ i.e., at the age $x + 1$ = 1,00,000 – 13,000 = 87,000

Col. 4. $qx$ = Probability of death per person in the specific age i.e., total deaths occurred. (Out of 1,00,000 = 13,000)
Probability = 13,000 ÷ 1,00,000 = 0.13
Similarly, at the age $x + 1$, 1300 persons died out of 87,000 live population then Probability = 1300 ÷ 87,000 = 0.01494.

Col. 5. $Px$ = 1 – Probability of surviving per individual person or $1 - qx$, i.e.; At age $x$, 1 – .13000 = .87000 and at age $x + 1$, 1– .01494 = .98506.

Col. 6. $Lx$ = Number of years lived by the cohort in the age $x$ to $x + n$ or

$fx$ of any two age groups ÷ 2.

Suppose,

$fx - 15 = 81925$ [col. : 3, row 15]

$fx - 16 = 81715$ [col. : 3, row 16]

$Lx = 163640 \div 2 = 81820$

Col. 7. $Tx$ = Total number of years lived by the cohort after exact age $x$. This can be found out from the reverse side of life table, i.e.,

At the age of 94 $Lx = 525$ and

at age 93 $Lx = 925$

then at age $x + 93$, total number of years lived by

Cohort = 525 + 925 = 1450 and at age $x + 92$,

it will be 525 + 925 + 1400 = 2850.

Col. 8. Ex = $Tx \div Fx$. This gives average life expectancy.

In short, the life table is based on the age of death period of a particular population. By studying this table, we can show the probability of death of any person of any particular age group. It is to be noted that every person of a particular age group does not die according to the estimate of the life table. The life table only shows a trend.

**Importance of Life Table**

Life tables have been constructed by **Graunt**, **Reed** and **Merrell**, **Keyfitz**, **Greville** and other demographers for estimating population trends regarding death rates, average expectation of life, migration rates, etc. We detail below the uses of life tables:

1. Life table is used to project future population on the basis of the present death rate.

2. It helps in determining the average expectation of life based on age specific death rates.

3. The method of constructing a life table can be followed to estimate the cause of specific death rates, male and female death rates, etc.

4. The survival rates in a life table can be used to calculate the net migration rate on the basis of age distribution at 5 or 10 year interval.

5. Life tables can be used to compare population trends at national and international levels.

6. By constructing a life table based on the age at marriage, marriage patterns and changes in them can be estimated.

7. Instead of a single life table, multiple decrement life tables relating to cause specific death rate, male and female death rates, etc. can be constructed for analysing socio-economic data in a country.

8. Life tables are particularly used for formulating family planning programmes relating to infant mortality, maternal deaths, health programmes, etc. They can also be used for evaluating family planning programmes.

9. Now a days, life tables are used by life insurance companies in order to

estimate the average life expectancy of persons, separately for males and females. They help in determining the amount of premium to be paid by a person falling in a specific age group. Besides, if an insured person dies before the policy matures, the life table provides economic support to the insurance company without facing financial loss and it is able to give the insured amount to the legal heirs of the deceased.

### 9·5·5. Assumptions, Description and Construction of Life Tables.

***Assumptions.*** The following are a few simplified assumptions which are used in the construction of the life tables.

(*i*) The cohort is closed for emigration or immigration. In other words, ***there is no change in the census except the losses due to deaths.***

(*ii*) Individuals die at each age according to pre-determined schedule which is fixed and does not change.

(*iii*) The cohort originates from some standard number of births, say 10,000 or 1,00,000 which is called the *radix* of the table.

(*iv*) The deaths are distributed uniformly over the period $(x, x+1)$ for each $x$ (except for first few years). In other words, deaths are uniformly distributed between one birthday and the next.

***Description of a Life Table.*** A typical life table has generally the following columns :

TABLE 9·11 : COLUMNS OF A LIFE TABLE

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| $x$ | $l_x$ | $d_x$ | $q_x$ | $p_x$ | $m_x$ | $\mu_x$ | $L_x$ | $T_x$ | $e_x^0$ | $e_x$ |

The various symbols entering in this table have already been defined in the preceding sections. Here we shall very briefly outline the various steps required for completing the table, starting with the second column. Of course, these relations have been obtained under the assumptions given above. For $x = 0, 1, 2, \ldots$, we have

1. $d_x = l_x - l_{x+1}$ 2. $q_x = \dfrac{d_x}{l_x}$ 3. $p_x = 1 - q_x = \dfrac{l_{x+1}}{l_x}$

4. $m_x = \dfrac{2q_x}{2-q_x}$ 5. $\mu_{x+(1/2)} = m_x$ 6. $L_x = l_x - \frac{1}{2}d_x = \frac{1}{2}(l_x + l_{x+1})$

7. $T_x = L_x + L_{x+1} + L_{x+2} + \ldots \Rightarrow T_{x+1} = T_x - L_x$ 8. $e_x{}^0 = \dfrac{T_x}{l_x}$ 9. $e_x = e_x{}^0 - \dfrac{1}{2}$

***Remark.*** The columns (5), (6) and (7) do not occur in all the life tables. However, the remaining columns are a must in any life table.

***Construction of Life Table.*** It will be seen, as discussed below, that the complete life table can be constructed if we can compute the quantities $q_x$ (or $p_x$) for all $x > 0$. The only other data which is needed is the *radix* $l_0$. The $q_x$ column is thus called the *pivotal column* of the life table. Starting with radix $l_0$ and $q_x$, $(x = 0, 1, 2, \ldots)$, we have

$$d_0 = l_0 q_0 \Rightarrow l_1 = l_0 - d_0 \quad ; \quad d_1 = l_1 q_1 \quad \text{or} \quad l_2 = l_1 - d_1$$

and so on. Form these values of $l_x$, $(x = 0, 1, 2, \ldots)$ the columns $L_x$, $T_x$ and $e_x{}^0$ of the table can now be completed by using the relations : $L_x = \frac{1}{2}(l_x + l_{x+1})$, $T_x = \sum_{i=x}^{\infty} L_i$, $e_x{}^0 = (T_x/l_x)$.

***Remarks*** **1.** We have seen above that the complete life table can be constructed if we know the values of $l_0$ and $q_x$ $(x = 0, 1, 2, \ldots)$. The values of $q_x$ are obtained from (9·54), where the corresponding values $m_x = d_x / L_x$ are computed on the basis of census records and death registration data. It should be borne in mind that the construction of the life tables from the death registers as outlined above will yield reliable results only if the population has been stationary over a period at least equal to the age of the oldest survivor.

**2.** For reference, we reproduce in Tables 9·10 and 9·11, the All India Life Tables of Males and Females separately for the decade 1961— 1970, as prepared by Registrar-General of India. It may be observed that in these tables $L_x \neq \frac{1}{2}(l_x + l_{x+1})$ for initial values of $x$, since the assumption that deaths are uniformly distributed over the years is not satisfied for $x = 0, 1, 2, 3$. The values in the tables have been obtained by a more complicated formula.

TABLE 9·12 : LIFE TABLES INDIA, MALES 1961–1970

| Age | Number living at age x | Survival ratio | Mortality rate | Number living between ages x and x + 1 | Number living above age x | Expectation of life |
|---|---|---|---|---|---|---|
| $x$ | $l_x$ | $p_x$ | $q_x$ | $L_x$ | $T_x$ | $e_x^0$ |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0 | 100000 | 0.86500 | 0.13500 | 89175 | 4707539 | 47.1 |
| 1 | 86500 | 0.94944 | 0.04056 | 84430 | 4617664 | 53.3 |
| 2 | 82992 | 0.98744 | 0.01056 | 82440 | 4533234 | 54.6 |
| 3 | 81950 | 0.99315 | 0.00685 | 81658 | 4450794 | 54.3 |
| 4 | 81388 | 0.99422 | 0.00578 | 81149 | 4369136 | 53.7 |
| 5 | 80918 | 0.99509 | 0.00491 | 80720 | 4287987 | 53.0 |
| 6 | 80521 | 0.99577 | 0.00423 | 80351 | 4207267 | 52.3 |
| 7 | 80181 | 0.99627 | 0.00373 | 80032 | 4126916 | 51.5 |
| 8 | 79882 | 0.99659 | 0.00341 | 79746 | 4046884 | 50.7 |
| 9 | 79609 | 0.99672 | 0.00328 | 79479 | 3967138 | 49.8 |
| 10 | 79348 | 0.99698 | 0.00302 | 79229 | 3887659 | 49.0 |
| 11 | 79109 | 0.99736 | 0.00264 | 79004 | 3808430 | 48.1 |
| 12 | 78900 | 0.99755 | 0.00245 | 78803 | 3729426 | 47.3 |
| 13 | 78706 | 0.99756 | 0.00244 | 78611 | 3650623 | 46.4 |
| 14 | 78514 | 0.99739 | 0.00260 | 78411 | 3572012 | 45.5 |
| 15 | 78309 | 0.99724 | 0.00276 | 78201 | 3493601 | 44.6 |
| 16 | 78092 | 0.99722 | 0.00278 | 77984 | 3415400 | 43.7 |
| 17 | 77875 | 0.99715 | 0.00258 | 77764 | 3337416 | 42.9 |
| 18 | 77653 | 0.99703 | 0.00297 | 77538 | 3259652 | 42.0 |
| 19 | 77422 | 0.99688 | 0.00312 | 77301 | 3112114 | 41.1 |
| 20 | 77181 | 0.99686 | 0.00314 | 77060 | 3104813 | 40.2 |
| 21 | 76938 | 0.99676 | 0.00324 | 76813 | 3027753 | 39.4 |
| 22 | 76689 | 0.99667 | 0.00333 | 76561 | 2950940 | 38.5 |
| 23 | 76433 | 0.99627 | 0.00373 | 76065 | 2874379 | 37.6 |
| 24 | 76148 | 0.99566 | 0.00434 | 75983 | 2708314 | 36.7 |
| 25 | 75818 | 0.99507 | 0.00493 | 75632 | 2722331 | 35.9 |
| 26 | 75445 | 0.99462 | 0.00538 | 75242 | 2646699 | 35.1 |
| 27 | 75039 | 0.99414 | 0.00586 | 74820 | 2571457 | 34.3 |
| 28 | 74599 | 0.99364 | 0.00639 | 74463 | 2496637 | 33.5 |
| 29 | 74125 | 0.99311 | 0.00689 | 73871 | 2422274 | 32.7 |
| 30 | 73615 | 0.99307 | 0.00693 | 73360 | 2348403 | 31.9 |
| 31 | 73105 | 0.99225 | 0.00775 | 72822 | 2275043 | 31.1 |
| 32 | 72538 | 0.99149 | 0.00851 | 72230 | 2202221 | 30.4 |
| 33 | 71921 | 0.99080 | 0.00920 | 71591 | 2129991 | 29.6 |
| 34 | 71260 | 0.99017 | 0.00983 | 70910 | 2058400 | 28.9 |
| 35 | 70559 | 0.98949 | 0.01051 | 70189 | 1987490 | 28.2 |
| 36 | 69818 | 0.98874 | 0.01126 | 69425 | 1917301 | 27.5 |
| 37 | 69032 | 0.98812 | 0.01188 | 68622 | 1847876 | 26.8 |
| 38 | 68212 | 0.98755 | 0.01245 | 67787 | 1779254 | 26.1 |
| 39 | 67362 | 0.98705 | 0.01295 | 66926 | 1711467 | 25.4 |

**9·5·6. Uses of Life Tables.** Although the basic objective of life tables is to give a clear picture of the age distribution of mortality in a given population group, it has been used widely in a large number of spheres. Today life table is widely accepted as important basic material in demographic and public health studies. In the words of **William Farr**, life table is the 'Biometer' of the population. We enumerate below some of important *applications* of life tables.

1. ***For Use by Actuaries in Insurance.*** Life tables are indispensable for the solution of all questions concerning the duration of human life. These tables, based on the scientific use of statistical methods, are the key stone or the pivot on which the whole science of life assurance hinges. Life tables form the basis for determining the rates of premiums to be paid by persons of different age groups, for various amount of life assurance. Life tables provide the actuarial science with a sound foundation, converting the insurance business from a mere gambling in human lives to the ability to offer well calculated safeguard in the event of death.

2. ***For Population Projections.*** Life tables are used by demographers to devise measures such as '*Net Reproduction Rate*' to study the rate of growth of population . They have also been used in preparation of population projections by age and sex, *i.e.*, in estimating what the size of the population will be at some future date.

3. ***For Comparison of Different Populations.*** Life tables for two or more different groups of population may be used for the relative comparison of various measures of mortality such as death rate, expectation of life at various ages, etc. Of particular interest is the comparison of $e_x^0$, the average longevity for members of a population.

4. Life tables are as well used by the government and the private establishments for determining the rates of retirement benefits to be given to its employees or for formulating various programmes for retired persons.

5. Since a life table depicts the distribution of the people according to age and sex, it is extremely useful in planning in respect of education and for predicting the school going population in connection with school building programmes.

6. Life tables are also used :

(*i*) For making policies and programmes relating to public health, by the government and public administration.

(*ii*) To evaluate the impact of family welfare programmes on the population growth.

(*iii*) For estimating the probable number of future widows and orphans in a community, and

(*iv*) For computing the approximate size of future labour force and military forces, etc.

***Example 9·6.*** *Complete the life table of the population of a certain types of insects, x being the age in days and $l_x$ = 1,000 for x = 0 :*

| x... | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| $q_x$... | 0·120 | 0·005 | 0·010 | 0·050 | 0·100 | 0·500 | 0·800 | 0·900 | 0·950 |

**Solution.** Since we are given the values of $q_x$, in order to complete the life table, first of all we shall find the values of $l_x$, (x = 0, 1, 2, ..., 8) by using the relations :

$$q_x = \frac{d_x}{l_x} \quad \text{and} \quad l_{x+1} = l_x - d_x$$

We are given $l_0 = 1{,}000$

$\therefore\ d_0 = l_0 q_0 = 1000 \times 0{\cdot}12 = 120{\cdot}0$

$l_1 = l_0 - d_0 = 1000 - 120 = 880$

$d_1 = l_1 q_1 = 880 \times 0{\cdot}005 = 4{\cdot}0$

$l_2 = l_1 - d_1 = 880 - 4 = 876$

$d_2 = l_2 q_2,\ l_3 = l_2 - d_2$ and so on.

The values of $l_x$ and $d_x$, (x = 0, 1, 2, ... 8) obtained on using (*) repeatedly are given in the *Table 9·13.*

TABLE 9·14

| x | $q_x$ | $l_x$ | $d_x = l_x q_x$ |
|---|---|---|---|
| 0 | 0·120 | 1000 | 100 × 0·120 = 120 |
| 1 | 0·005 | 100 − 120 = 880 | 880 × 0·005 = 4·4 ≃ 4 |
| 2 | 0·010 | 880 − 4 = 876 | 876 × 0·010 = 8·76 ≃ 9 |
| 3 | 0·050 | 876− 9 = 867 | 867 × 0·050 = 43·35 ≃ 43 |
| 4 | 0·100 | 867− 43 = 824 | 824 × 0·100 = 82·4 ≃ 82 |
| 5 | 0·500 | 824 − 82 = 742 | 742 × 0·500 = 371·0 |
| 6 | 0·800 | 742 − 371 = 371 | 371 × 0·800 = 296·8 ≃ 297 |
| 7 | 0·900 | 371 − 297 = 74 | 74 × 0·900 = 66·6 ≃ 67 |
| 8 | 0·950 | 74 − 67 = 7 | 7 × 0·950 = 6·65 ≃ 7 |

The remaining columns of the life table, *viz.*, $L_x$, $T_x$ and $e_x^0$ can now be completed as discussed in *Example 9·4.*

***Example 9·7.*** *Fill in the blanks of the following table which are marked with question marks :*

| Age, x : | $l_x$ | $d_x$ | $q_x$ | $p_x$ | $L_x$ | $e_x^0$ |
|---|---|---|---|---|---|---|
| 20 | 6,93,435 | ? | ? | ? | ? | 35,081,126 |
| 21 | 6,90,673 | — | — | — | — | ? |

**Solution.** Taking age 20 x, *i.e.*, age 21 as x + 1, in the usual notations, we get

$d_{20} = l_{20} - l_{21} = 693435 - 690673 = 2762$

$$q_{20} = \frac{d_{20}}{l_{20}} = \frac{2762}{693435} = 0{\cdot}00398$$

$p_{20} = 1 - q_{20} = 1 - 0{\cdot}00398 = 0{\cdot}99602$

$$L_{20} = \frac{l_{20} + l_{21}}{2} = \frac{693435 + 690673}{2} = 692054$$

$T_{21} = T_{20} - L_{20} = 35081126 - 692054 = 34389072$

$$e_{20}^0 = \frac{T_{20}}{l_{20}} = \frac{35081126}{693435} = 50{\cdot}59$$

$$e_{21}^0 = \frac{T_{21}}{l_{21}} = \frac{34389072}{690673} = 49{\cdot}79$$

***Example 9·8.*** *Fill in the blanks in a portion of life table given below:*

| Age (in years) | $l_x$ | $d_x$ | $p_x$ | $q_x$ | $L_x$ | $T_x$ | $e_x^0$ |
|---|---|---|---|---|---|---|---|
| 4 | 95,000 | 500 | ? | ? | ? | 4,850,300 | ? |
| 5 | ? | 400 | ? | ? | ? | ? | ? |

**Solution.** In the usual notations, we have

$l_5 = l_4 - d_4 = 95000 - 500 = 94500$

$p_4 = \frac{l_5}{l_4} = \frac{94500}{95000} = 0{\cdot}9947$

$q_4 = 1 - p_4 = 1 - 0{\cdot}9947 = 0{\cdot}0053$

$l_6 = l_5 - d_5 = 94500 - 400 = 94100$

$p_5 = \frac{l_6}{l_5} = \frac{94100}{94500} = 0{\cdot}9958$

$q_5 = 1 - p_5 = 1 - 0{\cdot}9958 = 0{\cdot}0042$

$q_5 = 1 - p_5 = 1 - 0{\cdot}9958 = 0{\cdot}0042$

$L_4 = \frac{l_4 + l_5}{2} = \frac{95000 + 94500}{2} = 94750$

$L_5 = \frac{l_4 + l_5}{2} = \frac{94500 + 94100}{2} = 94300$

$e_4^0 = \frac{T_4}{l_4} = \frac{4850300}{95000} = 51{\cdot}06$

$T_5 = T_4 - L_4 = 4850300 - 94750 = 4755550$

$e_5^0 = \frac{T_5}{l_5} = \frac{4755550}{94500} = 50{\cdot}32.$

**Example 9·9.** *Given that the complete expectation of life at ages 30 and 31 for a particular group are respectively 21·39 and 20·91 years and that the number living at age 30 is 41,176; find (i) the number that attains the age 31 and (ii) the number that will die without attaining the age 31.*

**Solution.** (*i*) In the usual notations we want the value of $l_{31}$ and we are given :

$$\overset{0}{e}_{30} = 21{\cdot}39,\ \overset{0}{e}_{31} = 20{\cdot}90 \quad \text{and} \quad l_{30} = 41176$$

$$\therefore \quad e_{30} = \overset{0}{e}_{30} - \frac{1}{2} = 21{\cdot}39 - 0{\cdot}5 = 20{\cdot}89\ ; \quad \text{and} \quad e_{31} = \overset{0}{e}_{31} - \frac{1}{2} = 20{\cdot}91 - 0{\cdot}5 = 20{\cdot}41$$

Here we shall use the formulae :

$$p_x = \frac{l_{x+1}}{l_x} = \frac{e_x}{1 + e_{x+1}} \qquad \ldots(*)$$

Taking $x = 30$, we get

$$\frac{l_{31}}{l_{30}} = \frac{e_{30}}{1 + e_{31}} \Rightarrow l_{31} = \frac{l_{30}e_{30}}{1 + e_{31}} = \frac{41176 \times 20{\cdot}89}{20{\cdot}41} = 40176$$

(*iii*) The number of persons who die without attaining the age 31 is equal to the numbers of persons dying between the age period 30 and 31 and is given by :

$$d_{30} = l_{30} - l_{31} = 41176 - 40176 = 1000.$$

**Example 9·10.** *The number of persons dying at age 75 is 476 and the complete expectation of life at 75 and 76 years are 3·92 and 3·66 years. Find the numbers living at ages 75 and 76.*

**Solution.** In the usual notations, we are given

$$\overset{0}{e}_{76} = 3{\cdot}92,\ \overset{0}{e}_{75} = 3{\cdot}66,\ d_{75} = 476. \text{ We want } l_{75} \text{ and } l_{76}$$

We have

$$e_{75} = \overset{0}{e}_{75} - 0{\cdot}50 = 3{\cdot}42\ ;\quad e_{7{\cdot}6} = \overset{0}{e}_{7{\cdot}6} - 0{\cdot}50 = 3{\cdot}16$$

As in the above example, we get from (*)

$$l_{76} = \frac{l_{75}e_{75}}{1 + e_{76}} = \frac{3{\cdot}42}{4{\cdot}16} l_{75} = 0{\cdot}8221\, l_{75}$$

Also $\quad d_x = l_x - l_{x+1} \Rightarrow d_{75} = l_{75} - l_{76} = 476$ (given)

$$\therefore \quad l_{75} - 0{\cdot}8221\, l_{75} = 476 \Rightarrow (1 - 0{\cdot}8221)\, l_{75} = 476$$

$$\Rightarrow \quad l_{75} = \frac{476}{0{\cdot}1779} = 2675{\cdot}66 \simeq 2676$$

and $\quad l_{76} = l_{75} - d_{75} = 2676 - 476 = 2200.$

# Chapter - I
# Fertility: Measures and Determinants

Today fertility, population problems and fertility rate are being studied by the policy makers, both in the government and outside. There is no aspect of human life, which is not influenced by fertility. In the words of Thomson and Lewis[1], "The fertility of women has always been a matter of vital concern to the all peoples."

They further define, "Fertility is generally used to indicate the actual reproductive performance of a woman or groups of women. The crude birth rate (number of birth per 1000 population per year) is only one measure of fertility."

Barnard Benjamin[2] defines fertility by saying "Fertility measures the rate at which a population adds to itself by births and is normally assessed by relating the number of births to the size of some section of population, such as the number of married couples, number of women of child bearing age, i.e. an appropriate yard stick of potential fertility".

In the modern society, it is most essential that fertility rate should be appropriately assessed and checked, so that the government and planners become conscious of the magnitude of the problem. The fertility rate of a nation has been most important measure and a matter of great interest for the population Geographers all over the world. Measurement of fertility has become very essential in the face of growing gap between the economic resources and population growth of the globe. There is also the question of political administration of growing population of various sections of the society. The term fertility refers to the actual bearing of children. It is a complex social phenomenon; therefore it is difficult to measure it. There are mathematical measures of fertility in terms of live births. These methods are simple as well as complex and differ in their effectiveness. They also differ in their characteristics and are used in different situations. Thus objective of this section is to identify such measures of fertility which are appropriate for the problem at hand. These measures are (1) Child-women ratio (2) Crude birth rate (3) General fertility rate (4) Age specific fertility rate (5) Total fertility rate (6) Gross reproduction rate (GRR) (7) Net reproduction rate (NRR) and Cohort fertility rate.

## 1.1 FERTILITY MEASURES

**Child-Women Ratio:**

It is a ratio, which a population has between the women and the children. A child is considered to be a baby between the age of 1 to 5 years. It is expressed in terms of number of children below five years of age per thousand females of reproductive age group (15-49 years).

$$\text{Child-women ratio} = \frac{P(0\text{-}5)}{FP(15\text{-}49)} \times 1000$$

Where,

P(0-5) = number of children under 5 years of age

FP(15-49) = female population in child bearing age group (15-49 years)

It represents the number of children under 5 years of age per 1000 women of child bearing age. Figures from census as well as registration office are used to calculate the ratio.

**The Crude Birth Rate:**

CBR is a ratio of total registered live births to the total population during a specific year, multiplied by 1000.

$$CBR = \frac{B}{P} \times 1000$$

Where,

B is number of live births in a year

P is the mid-year total population

It gives a fraction of births per person. This rate is called crude because it ignores all differences in composition of the population. Firstly, the entire population can not be in reproducing age group. Only female population that too in the age group (15-49 years) can give births. It is observed that the proportion of the population that lies outside the child bearing age is not constant for one population to another, but varies according to the levels of fertility and mortality.

**The General Fertility Rate:**

Contrary to crude birth rate this measure uses the number of women of child bearing age in a population as a base for the calculation rather than total population. It is a great improvement over CBR because in it only the population of reproductive age group is taken into consideration. It considers only the female population of reproductive age group. General fertility rate is the number of births that occur in a year per 1000 women of child bearing age. In other words it is a ratio of total yearly registered births to the population of women of child bearing age. The purpose is to restrict the denominator of the rate to potential mothers by excluding all men and large groups of women not exposed to the risk of child bearing by reason of age. This rate is calculated with the help of following formula:

$$GFR = \frac{B}{P\ (15\text{-}49)} \times K$$

Where,

P (15-49) = mid-year female population in age group (15-49)

B = registered live births in the year

K = 1000

The GFR is usually four to five times as high as the crude birth rate in the same population because the women of these ages normally constitute form one fifth to one fourth of the total population. It is with the help of the rate that it becomes possible to eliminate the influence of any differences in the proportion of males and females of population.

**The General Marital Fertility Rate (GMFR):**

It is the most commonly used measure of fertility. This measure is improvement over GFR, as married female population in reproducing age group is used in the denominator against total female population (both married and unmarried). It is only married female who are exposed to births.

It is calculated as

$$GMFR = \frac{B}{MF\ (15\text{-}49)} \times 1000$$

Where,

B = total number of live births in a year

MF (15-49) = mid year population of married female in the reproductive age

This rate can be effectively used for comparing fertility between two population.

**The Age Specific Fertility Rate (ASFR):**

It is obtained by dividing the number of births to the mothers of each age in that year by the number of women of this age in the population at that date and multiplying this figure by 1000. The age specific birth rate then, is the number of births per 1000 women of a given age per year. Under this system women of reproductive sub-age groups, are divided and rate for each sub-group is separately found out. It is calculated by using the following formula:

$$ASFR = \frac{bi\ (x-y)}{pi\ (x-y)} \times K$$

Where,

bi(x-y) = number of births registered during the year to women in the age interval (x–y). Usually such an interval is of 5 years.

pi(x-y) = mid-year population of women in the same age group (x–y)

K = 1000

In simpler way we can write

$$ASFR = \frac{\text{Births in specified age group}}{\text{mid-year women population of that age group}} \times K$$

The ASFR is preferred over other fertility rates, since it considers the fact that women of all reproductive age groups do not have same fertility. It is also possible to calculate total and cumulative fertility rates. However, the ASFR's do not give a single measure of fertility to indicate its level in a society.

**Total Fertility Rate (TFR):**

It is an expression of the number of births that would occur to a woman who has experienced a particular set of ASFR's as she has passed through the reproductive period. It is obtained by adding the ASFR's for women at each age, however when 5 year age groups are used, the total must be multiplied by 5 in order to estimate the sum of the rates at each individual age.

It is obtained as

$$\text{TFR} = \sum_{i=15}^{49} \left( \frac{bi}{pi} \right) \times K$$

Where,

bi = number of live births registered during the year to mother of age i.

pi = mid-year population of women of the same age.

K = 1000

This measure is regarded as the best single cross sectional measure of fertility. It is most sensitive and meaningful measure of fertility. If the TFR is two, it means that parents are replacing themselves and the population remains static. However in the end the population with TFR at two, will decline as all the mothers will not survive till the end of the reproductive period (Srivastava, O.S., 1983)[3].

**The Gross Reproductive Rate (GRR):**

The total fertility includes all births, both male and female. The GRR shows how many girls babies, potential future mothers, would be born to 1000 women passing through their child bearing years, if the age specific birth rates of a given year remained constant and if no women entering the child bearing period died before reaching menopause. It represents the average number of daughters who would replace their mothers, assuming that the age and sex specific fertility rate for the current period were to continue indefinitely (Woods, R., 1979)[4].

The rate is calculated by adding ASFR's for female births only for ages 15-49. The formula is

$$\mathrm{GRR} = \sum_{i=15}^{49} \left( \frac{FBi}{Fi} \right) \times 1000$$

Where,

FBi = number of female births to the women in age group i.

Fi = number of females in the age group i.

A GRR of over 1000 should mean that the female population is more than capable of replacing itself with an equivalent number of daughters. The main defect in NRR lies in the assumption that the age specific birth and death rates will remain constant during the generation.

**The Net Reproduction Rate (NRR):**

It is used to indicate generational replacement. It is quite easy to interpret. An NRR of one, means that a population will replace itself but will not grow. An NRR of less than one indicate that the population is not replacing itself and if the rate continues, the population will decline. If NRR is more than one, it means that the population is not only replacing itself but it is also growing (Kammeyer and Ginn, 1988)[5].

**Cohort Fertility Rate:**

It is a relatively new refined fertility rate now coming into use. The measure derives the name from the fact that it uses as its base for calculations all the women born in a given year that is called a cohort. In order to avoid the interpretative problems associated with measures of one point-in-time reproductive performance, demographers have increasingly adopted measurers of cohort fertility. A cohort being regarded in these cases, as a group of women born or married in a particular year (Thompson, W.S., 1963)[6].

## 1.2 FERTILITY DETERMINANTS

Levels of Human Fertility differ significantly according to economical, occupational, geographical, social and religious groups. A country's different regions and different families in a region have different fertility levels. No two neighbours have the same fertility. It is determined, directly and indirectly, by a series of factors that either as a matter of individual desire or indirectly through socio-cultural interference impinges on the biological conditions for birth. Generally first of these is the proportion of female population of reproductive age living in a stable sexual union. At a second level, two easily identified factors, associated with the control of fertility contraception defined as a deliberate practice, including sterilization and abstinence, undertaken to reduce fertility. At the third level, are two behavioual variables that determine fertility, namely locational infecundiability and frequency of intercourse, lastly sterility and the durability of ova and sperm, are three variables, that determine fertility in a physiological rather than behavioural way. These determinants can be studied in four different categories, namely socio-cultural factors, direct factors, economic and literacy factors and religious factors.

**Socio-Cultural Factors:**

These are the factors, which are influenced by social customs and they in turn affect fertility. Normally however, the people do not ponder over these factors, which influence fertility. On the other hand these are treated as social values. Usually these factors instead of directly influencing fertility, indirectly influence it.

**i) Age of Puberty and Marriage:**

Fertility goes down when marriage takes place at a late stage. In Europe many people marry at a very late stage and in many more cases the people even do not marry at all. It is well known fact that fertility rate is higher in countries where marriage take place at comparatively early age as compared with the people who marry at late stage. In India marriage takes place at very young age, but in West Indies marriages take place at late stage but the boys and girls are permitted to have sex relations and even produce children before marriage. Thus it is not universally correct that fertility will be low, if the marriages take place at late stage. In India, in spite of the fact that marriages take place at young age, sexual relationship is socially permitted when the girl has reached puberty.

The mean age of women at marriage varies widely among populations. In traditional societies in Asia and Africa, the mean age at marriage of around 17 years is not uncommon. In contrast, the mean age at marriage in number of European population is about 25 years. Further, in most traditional societies virtually all women marry, but in developed countries the proportion of single women at age 50 often exceeds 10 percent (Potts and Selman, 1979)[7]. It may be pointed out that if all Indian women had got married after the age 19, there would have been a reduction of 30% in the birth rate by 1992 (Agarwal, S.N., 1965)[8].

**ii) Polygamy:**

Another indirect social factor, which influences fertility, is polygamy. It is a system under which a husband can have more than one wife. This system is not very popular these days. If polygamy is compared with a system where the husband has only one wife, then there is possibility that fertility per woman may be very low. But the facts have not supported this belief. When a husband begins to maintain more than one wife, then their first wives get more opportunities of meeting the husband and thus produce more children as compared with the wives, who are married at late stage and due to old age of the husband, the sexual meetings between the husband and the wife are very less. As such, chances of such wives producing children are considerably reduced. Since the husband himself is old and the wife is not permitted to have sexual exposures with other young men, the result is that birth of children per woman considerably goes down.

**iii) Separation and Divorce:**

It is not certain that after marriage, both the husband and the wife will always have cordial relations. There can be and in many case are unhealthy and strained relations between the two, which result either in separation or divorce. But separation always does not mean low fertility. It is related to many factors e.g. how frequent is the separation, what is separation period, the age of the children when the parents opt for separation, age of the parents themselves at the time of separation or divorce, the interval between the separation and remarriage, etc. A study conducted in Jamaica in 1954, showed that those couples, which have a tendency to always live closer to each other, have more fertility as compared with the couples, which remain away from each other. If separation and divorce takes place when the couple is young and still at an age when they can produce children then it may affect fertility, but not otherwise.

**iv) Widowhood:**

One another indirect social factor which quite obviously influences fertility is widowhood. It is because without her husband she cannot have legal children. The effect of widowhood on fertility depends on how soon she decides to remarry and at what age she becomes widow. If a widow decides to remarry immediately then fertility will not be affected. But if she decides to remarry at a very late stage or not to remarry at all, obviously fertility will be affected. Widow remarriage system depends on social conditions and attitudes of the people and differs from country to country. In India for a long time widow remarriage was discouraged, though the situation has changed now. It has been found that because of widowhood, the women has an average of one-half to one child less during her reproductive period (Dandekar, 1962)[9].

**v) Celibacy:**

Fertility is also affected by prevalence of celibacy in many sections of the society. Legal and social controls on marriages lead to no fertility at all. In India legally a boy cannot marry before the age of 25 and a girl 18 years. In Christian dominating societies, priest and nuns generally do not marry at all. These social and religious restrictions on marriages have a direct affect on fertility.

**vi) Postpartum Abstinence:**

In many families and societies restrictions are imposed upon husband and wife for sexual reunion after the birth of a child. Obviously if the period is quite long, the fertility will be less. If the period is less, the fertility will not be much affected.

**vii) Frequency of Coitus:**

Fertility also depends not only on the frequency of meeting husband and wife but also on precautionary measures against conception they take before such meetings. Because of this factor, despite more frequent meetings between husband and wife in U.S.A. than their counterpart in India, fertility among the Indian women is higher than the American women. Indians usually do not take precautionary measure against conception.

## Direct Factors:

For the last many decades population explosion has been the main worry of the social and political organizations. Governments have been perusing family planning programme to contain fertility.

The most important direct factor, which affects fertility, is the family planning programme. Every society is interested in checking fertility, people are being educated & convinced to check fertility by use of contraceptives, oral pills etc. Some people also resort to unnatural measures to control fertility such as abortion, infanticide etc. Common methods, which are used to check fertility, are as follows:

- **Oral pills** are being extensively used in developed countries by the women to check pregnancy. These are taken on regular basis for 20 days a month on the doctor's advice. They can be very effective aand useful for the women.

- **The loops** are used by women for checking fertility and chances of success in avoiding conceptions are about 90%. Loops can be removed at any time. They were introduced in India in 1970 and are a very effective method in checking fertility.

- **Condoms** are used by man at the time of the meeting. They are very effective and easily available in the market. Indian government supply condoms at very concessional rates. These are now being commonly used and proving to be very useful methods for controlling family size.

- Many times a women becomes pregnant when she does not wish to have any child and thus opt for abortion. In India it is quite lawful to have the pregnancy **medically terminated**. It is very difficult to assess the effect of abortion on the fertility because people are not willing to supply information due to legal & social reasons.

- The practice in **infanticide** directly affects the population size. The newborn children are killed in many societies for different reasons. In some families handicapped children or those born ill are killed at the time of their birth. In an Eskimo society children are killed because of shortage of food.

- In some part of India female children are killed because they are considered to be the burden on the family and their marriage is a very expensive affair because of dowry. This practice is also prevalent in few parts of China.

**Economic and Literacy Factors:**

Economic factors have always been responsible for the concentration of population. At places where chances of employment are more, the population will always be thick and vice-versa. Among the various economic determinants of human fertility the income level of the family is, of course, the most prominent. Although a negative correlation between income level and the family size has been observed. Yet the deliberate attempts to check the family size are more common to that section of a society, which has the widest gap between the desired, and actual income levels. It implies that the middle-income group, which normally is the most ambitious section of society, applied the strictest control over family size. In the lower income-group, where the children are considered as the potential source of augmenting the family income, the restrictions on the family size are the minimum.

In the higher income group where the supporting capacity of the family is unlimited, the family size is also kept low but not the lowest. Closely associated with this is the factor of standard of living, which is largely dependent upon the income level. However, the poorest, all over the world show high birth rates and richest low birth rate. Similarly the dietary habits of the people, which are also intimately related with the income level, have been considered as determinants of fertility. An inverse correlation between birth rate and protein intake has been observed in experiments on animals. It implies that high intake of protein may induce sterility.

However studies made on the basis of family income shows that fertility is high among couples with lower income, it declines as income increases and is again high among couples of higher income (Mukharjee, R.K. and Baljit, S., 1961)[10], (Majumdar, 1960)[11] also points out that fertility is high among couples with highest income.

**Education Factors:**

Literacy and education broadens horizon of people and breaks the barriers against the willingness to restrict the family size. Education is negatively associated with fertility. Davis observes that there is a curve linear relationship between the number of children and percentage of females who are literate (Davis, K. 1951)[12]. In many countries large increase in the level of education have occurred slightly before or around the same time as fertility decline (Coldwell, J.C., 1980)[13]. A study conducted in Mysore, reveals that the average number of children born to an illiterate female is 5.5, whereas for educated women it was found to be 3.4 children only (United Nations, 1961)[14].

**Religious Factors:**

Religion is considered to be an important factor affecting fertility (Clarke, J.I., 1985)[15]. A couple's understanding of the religious obligations towards its offspring, also affects the fertility pattern. Certain religious groups particularly Muslims and Roman Catholics consider it an ungodly act to resort to any conception control method. Most of them can be found to be conservative in the family limitation programme, though it cannot be said that they do not practice family planning. Since use of contraceptives and artificial methods of conception control are considered by them as anti-religious act, fertility rates are higher among them. Their religious leaders do not support, rather oppose, the very idea of family planning.

The study of differential fertility of various religions as well as ethnic groups has important social and political implications. An analysis of census data of India for about one hundred years (1881-1971) indicates that Muslims have invariably higher growth rates for each decade. In pre-partition India, the fertility of Muslims was about 15 percent higher than that of Hindus (Vasaria, L., 1974)[16].

Various studies in the West, show that the fertility of Catholics has exceeded that of non-Catholics in almost every country and socio-economic group (Jones, G. and Nortman, D., 1968)[17].

## References:


1. Hans Raj, "Fundamentals of Demography", Surjeet Publications 1984, pp. 86-87

2. Ibid., p.87.

3. Srivastava, O.S., "A Text book of Demography ......", Vikas Publishing House, New Delhi, 1983, pp. 24-25.

4. Woods, R., "Population Analysis in Geography", Longman, London, 1979, p. 96.

5. Kammeyer, K.C.H. and Ginn, H.H., "An Introduction to Population", Archive Books, New Delhi, 1988, p. 215.

6. Thompson, W.S. and Lewis, D.T., "Population Problems", McGraw Hills, New Delhi, 1963, p. 257.

7. Potts, M. and Selman, P., "Society and Fertility", 1999, London.

8. Agarwal, S.N., "Effect of rise in female marriage age on birth rate in India", UN World Population Conference, Belgrade No.WPC/WP/18, 1965, p.6.

9. Dandekar, "Widowhood and mean fertile union", Medical Digest, Vol. 30, 1962, pp. 69-78.

10. Mukherjee, R.K. and Baljit, S., "Social Profiles of a Metropolis", Bombay, 1961, p. 167.

11. Majumdar, D.N., "Social Contours of an Industrial City (Social Survey of Kanpur, 1954-55)", Ashian Publishing House, Bombay, 1960, pp. 160-64.

12. Davis, K., "The Population of India and Pakistan", Princeton University Press, 1951, p. 74.

13. Coldwell, J.C., "Mass education as a determinant of the timing of fertility decline", Population and Development Review, Vol. 6, 1980, p. 26.

14. United Nations, "The Mysore Population Study", Population Studies, No. 34, 1961, p. 119.

15. Clarke, J.I., "Islamic Population: Limited Demographic Transaction", Geography, 1985, Vol. 70, pp. 120-21.

16. Vasaria, L., "Religious differential fertility, in Ashish Bose et al. (eds.), Population in India Development, 1947-2000", Vikas Publishing House, 1974, p. 365.

17. Jones, G. and Nortman, D., "Roman Catholic Fertility and Family Planning", Studies in family planning, 1968, p.3.