UNIT 12 VITAL STATISTICS

Structure

12.0 OBJECTIVES

After going through this Unit, you will be able to:

- explain the sources of data in vital statistics;
- calculate various vital rates;
- explain the procedure of construction of life table; and
- appreciate the applications and limitations of life tables.

12.1 INTRODUCTION

Vital statistics is mainly concerned with the factors contributing to population growth. Some of these factors are birth rates, death rates, expectancy of life, and migration. As you go through this Unit you will be in a position to appreciate the importance and applications of vital statistics in economics. The main objectives of this Unit are to introduce some of the basic concepts of vital statistics, the data sources, how to measure various ratios, and what are the applications of these ratios in projecting the population, calculating life expectancy, uses in actuarial science, etc.

12.2 DATA SOURCES

The data for vital statistics are usually collected through the following four methods; viz., Registration, Census, Survey and Sample Registration System. We discuss these methods below:

i) **Registration Method:** This method consists of continuous and permanent recording of births, deaths, marriages, migration, etc. Many countries including India have made registration of births and deaths compulsory under the law. The registration office issues a certificate on registration of a birth or death. Although, the registration method is simple and effective it suffers from the problem that all the births and deaths that are occurring are not registered. This is because the law has not been enforced strictly, particularly, in rural India.

ii) **Census:** Almost all the countries in the world conduct census periodically to enumerate their population. The census provide the vital statistics information such as age, sex, marital status, education level, occupation, religion, etc. However, these information pertain to the census years only (once in ten years). The data for the years other than census years are not available.

iii) **Survey:** Surveys are conducted in areas where the registration method is not effective or not functioning properly. The surveys enable us to have required vital statistics of these regions.

iv) **Sample Registration System (SRS):** This is a large scale demographic survey conducted in India for providing reliable annual estimates of birth rate, death rate and other fertility and mortality indicators at the national and sub-national levels. The field investigation consists of continuous enumeration of births and deaths by a resident part-time enumerator, generally a teacher followed by an independent survey every six months by an official. The data obtained through these operations are matched. The unmatched and partially matched events are re-verified in the field and thereafter an unduplicated count of births and deaths is obtained. The SRS was initiated by the Office of the Registrar General, India on a pilot basis in a few selected states in 1964-65. It became fully operational during 1969-70 covering about 3700 sample units. Thereafter the sample size has been periodically increased. The frame was recently updated based on 1991 Census data.

12.3 USES OF VITAL STATISTICS

Vital statistics are useful in many spheres of human activity. Some important uses of vital statistics are as follows.

1) The vital statistics help us in understanding how the population profile of a country or a region within the country is changing. The profile of the population is in terms of age, sex, religion, births, deaths, migration, marriages, etc. These statistics help us in predicting the future population structure of a country or region.

2) The estimation of population trends and projections help the policy planners and administrators for better planning and evaluation of economic and social development programmes. For example, the transportation infrastructure is influenced directly by the number of people in an area.

3) The mortality statistics help us to improve the health conditions of the communities. For example, statistics on communicable diseases help the health authorities to improve the sanitary conditions of the area affected and improve medical facilities.

4) The actuarial science including life insurance is based on vital statistics. You will learn more about it in section 12.4 of this Unit.

12.4 MEASUREMENT OF POPULATION

The total population of a country is usually expressed at a particular point of time. For example, the latest census in India was conducted in 2001 and the total population of the country was found to be on 31.3.2001. The total population measured at a census is usually considered as accurate. As you may be aware, the census in India are conducted once in 10 years. The inter-censal data are estimated using the following methods.

12.4.1 Linear Interpolation Method

The estimation of total population for a given inter-censal year can be calculated using the following formula:

$$P_t = P_0 + \frac{n}{N}(P_1 - P_0) \qquad ...(12.1)$$

Where, P_t is estimated population at a given inter-censal year t
P_0 is population in the previous census
P_1 is population in the succeeding census
n is the number of years between the given year and the previous census year
N is the number of years between the two census years

The above method provides us a good estimate at a constant rate between the inter-censal years.

Example 12.1: The total population of India in 1991 census was 846 million and in 2001 census was 1027 million. Calculate the total population of India in 1996.

Here, $P_0 = 846$, $P_1 = 1027$, $N = 10$, $n = 5$

Therefore, $P_{1996} = 846 + \frac{5}{10}(1027 - 846) = 936.5$ million.

The limitation of the above method is that we can estimate the population only for the years between two census years. We cannot have the estimates for the future years.

12.4.2 Using Compound Growth Rate Formula

Normally it was observed that the population growth takes place in a geometrical progression. In case the base year population and the population compound growth rate (between the base census year and succeeding census year) are known, we can estimate the total population for a given year using the following formula.

$$P_t = P_0(1+r)^n$$

where, r is the compound growth rate (between the base census year and succeeding census year)
n is the number of years from the base year (usually previous census year)

P_0 is the base year (usually previous census year)
P_t is the estimated population at a given year t from the base year

Example 12.2: The population of a small town in 1991 was 50500. The compound growth rate of the population of that town between 1991 and 2001 was 0.025. Estimate the population of the town for the year 2005 (assuming that the population growth rate will be the same beyond 2001).

Here, we are given $P_0 = 50500$, $r = 0.025$, and $n = 14$ (since 2005–1991 = 14)

Therefore, $P_{2005} = 50500\ (1 + 0.025)^{14} \quad = 71355$

12.4.3 Natural Increase and Net Migration Method

You know that the census gives us the total population. Similarly, the total number of births, deaths, and migration statistics are obtained from registrars. The population of an area increase by:

i) Natural increase (that is, total number of births – total number of deaths)
ii) Net migration (that is, total number of people immigrated to the area – total number of people emigrated out of the area).

The population for a given period is calculated using the following formula.
$P_t = P_0 + (B–D) + (I–E)$

Where, P_t is the estimated population at a given year *t* from the base year (usually previous census year)

P_0 is the base year (usually previous census year)

B and D are the total number of births and deaths respectively during the base year to the year t.

I and E are the total number of immigrants and emigrants respectively during the base year to the year *t*.

Example 12.3 : The population of a small town in 2001 census was 22000. From 2001 to 2003 the number of births, deaths, immigrants and emigrants are 800, 150, 2500 and 1500 respectively. Find the total population of the town in 2003.

Here, $P_0 = 22000$, $B = 800$, $D = 150$, $I = 2500$, $E = 1500$

Therefore, $P_{2003} = 22000 + (800–150) + (2500–1500)$
$= 23650$

Check Your Progress 1

The following table gives information on mid-year total population of India and annual compound growth rates of population.

Year	Population (Crores)	Period	Compound growth rate (%)
1950	36.99	1950-60	1.9
1960	44.59	1960-70	2.2
1970	55.50	1970-80	2.1
1980	68.70	1980-90	2.0
1990	84.17	1990-2000	1.8
2000	100.27	—	

Source: US Census Bureau: IDB Summary Demographic Data for India

Note that the compound growth rates are in terms of percentage. Divide it by 100 to get the required r. For example, for the period 1950-60 the compound growth rate is 1.9%. Therefore, r = 1.9/100 = 0.019.

On the basis of the above table answer the questions below:

1) Find the mid-year population for the following years using linear interpolation method.

Year	Mid-year population
1954	
1966	
1973	
1985	
1998	

2) Find the mid-year population for the following years using compound growth rate method.

Year	Mid-year population
1954	
1966	
1973	
1985	
1998	

3) Compare the above two methods and draw your conclusions.

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4) Briefly explain different data sources for vital statistics.

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5) What are the important uses of vital statistics?

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12.5 VITAL RATES

Normally, the data on vital statistics are available in the form of number of births, number of deaths, etc. In order to have a meaningful utility of these data we generally transform this data into some vital rates or ratios. Number of births or deaths in a year per 100 persons is usually low and would result in small fractions. The changes in these ratios would also be not perceptible. In order to avoid this problem, vital rates are expressed on the basis of per thousand persons. In this section you will learn some important vital rates.

12.5.1 Crude Birth Rate

The crude birth rate is defined as the number of births per 1000 population in a specific community or region. To calculate the crude birth rate we use the following formula :

$$\text{Crude birth rate} = \frac{\text{Annual Number births (in a community or region)}}{\text{Annual mid year population (of the community or region)}} \times 1000$$

The crude birth rate tells us at what rate the births are occuring in a region or community.

Example 12.4 : The mid-year population and number of births occurred of a tribal community in Madhya Pradesh in 1995 are 40,000 and 1200 respectively. Find the crude birth rate.

Here, we have 1995 mid-year population = 40000 and the 1995 number of births = 1200

$$\text{Crude birth rate} = \frac{1200}{40000} \times 1000$$

$$= 30 \text{ per 1000 persons per annum}$$

12.5.2 Crude Death Rate

The crude death rate is defined as the number of deaths per 1000 population in a specific age group or sex group or community or region. To calculate the crude death rate we use the following formula.

$$\text{Crude Death Rate} = \frac{\text{Annual number of deaths (in a specific age group or sex group or community or region)}}{\text{Annual mid year population (of the specific age group or sex group or community or region)}} \times 1000$$

The crude death rate tells us at what rate the deaths are happening in a age group, sex group or region or community.

Example 12.5: The mid-year population and the number of deaths registered in 2001 for a town in Maharashtra among females are 25000 and 245 respectively. Find the crude death rate.

Here, we have 2001 mid year female population = 25000 and the number of deaths in 2001 =245.

$$\text{Crude death rate (females)} = \frac{245}{25000} \times 1000$$

$$= 9.8 \text{ per 1000 persons per annum among females.}$$

12.5.3 Crude Rate of Natural Increase

The crude rate of natural increase is defined as the rate at which a population increases in a given year because of a surplus of births over deaths expressed as per 1000 persons.

The annual natural increase is measured as: annual number of births – annual number of deaths.

The formula for calculating the crude rate of natural increase is:

$$\text{Crude rate of natural increase} = \frac{\text{Annual natural increase}}{\text{Annual mid year population}} \times 1000$$

$$= \text{crude birth rate} - \text{crude death rate}$$

The crude rate of natural increase for a given year tells us at what rate natural increase has added the population over the year.

Example 12.6 : In India the crude birth rate and crude death rates in 1997 are 27.2 and 8.9 respectively. Find the crude rate of natural increase.

Crude rate of natural increase = 27.2 – 8.9
= 18.3 per 1000 per annum

12.5.4 Rate of Net Migration

Migration is defined as the movement of people across a specific boundary of a region for the purpose of establishing a new or semi permanent residence. Immigrants are those who have come into the region and eminigrants are those who have moved out of the region.

The annual net migration is defined as: Annual number of immigrants – annual number of emigrants

The formula for calculating the annual rate of net migration is:

$$\text{Annual rate of net migration} = \frac{\text{Annual net migration}}{\text{Annual mid year population}} \times 1000$$

The annual rate of net migration tells us at what rate the net migration has added to the population over the course of the year.

Example 12.7: In 2002 for a region the annual number of immigrants, emigrants, and mid–year population are given as 6500, 5200 and 66700 respectively. Find the annual rate of net migration.

Here, we have the number of immigrants	= 6500
the number of emigrants	= 5200
mid–year population	= 66700

Annual net migration = 6500 – 5200 = 1300

$$\text{Annual rate of net migration} = \frac{1300}{66700} \times 1000$$

$$= 19.7 \text{ per 1000 per annum}$$

12.5.5 Rate of Total Increase

The total increase in population is measured as:

Annual natural increase + annual net migration.

$$\text{Rate of total increase} = \frac{\text{Annual total increase}}{\text{Annual mid year population}} \times 1000$$

$$= \text{crude rate of natural increase} + \text{rate of net migration}$$

The rate of total increase for a given year tells us the rate at which the population has increased over the year.

Example 12.8 : The annual natural increase, annual net migration, and annual mid-year population in 1998 for a region are recorded as 1500, 500 and 50000 respectively. Find the rate of total increase.

Here, we have

Annual natural increase = 1500
Annual net migration = 500
Mid year population = 50000

Annual total increase = 1500 + 500 = 2000

$$\text{Rate of total increase} = \frac{2000}{50000} \times 1000$$

$$= 40 \text{ per 1000 per annum.}$$

12.5.6 Infant Mortality Rate

The infant mortality rate is defined as the number of deaths of infants (less than one year old) per 1000 live births in a given year. The formula to calculate the infant mortality rate is given as:

$$\text{Infant mortality rate} = \frac{\text{Annual infant deaths (of males or females or total)}}{\text{Annual live births (of males or females or total)}} \times 1000$$

The infant mortality rate tells us for a given year the chances of a birth failing to survive one year life. The infant mortality rates can be calculated separately for males and females.

Example 12.9 : In 1997 for a small town the total number of live births and infant deaths among females are recorded as 3000 and 25 respectively. Find the infant mortality rate among females.

Here, we have

Annual live female births = 3000
Annual infant deaths = 25

$$\text{Infant mortality rate} = \frac{15}{3000} \times 1000$$

$$= 8.33 \text{ per 1000 per annum}$$

Check Your Progress 2

The provisional estimates of crude birth rate, crude death rate, natural growth rate and infant mortality rate in India for the year 1997 are as follows:

Vital Rate	Total	Rural	Urban
Birth rate	27.2	28.9	21.5
Death rate	8.9	9.6	6.5
Natural growth rate	18.3	19.2	15.0
Infant mortality rate	71	77	45

Source: Sample Registration System Bulletin, October 1998

Observe that all the vital rates are higher in rural areas than in urban areas. Write one most significant reason for each of the following:

1) The birth rate in rural areas is high because

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2) The death rate in urban areas is low because

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3) The infant mortality rate in rural areas is high because

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12.6 LIFE TABLES

The life expectancy is defined as the average number of additional years a person could expect to live if the current mortality trends continue for the rest of that person's life. A life table is a tabular display of life expectancy and probability of dying at each age or age group for a given population, according to the age-specific death rates prevailing at that time.

The life table gives us an organised complete picture of a population's mortality.

We can explain it with an example. We start with a group (usually called cohort) of 100,000 female births and estimate the number which will survive to every age or age group, if they are subjected to the existing mortality conditions. We can say, for example, that out of 100,000 initial female births 95,000 will reach the age of 15 years, 92,500 the age of 25 years and so on, and the mean age at which all 100,000 will die is 72 years.

The construction of a life table is a simple process. It involves the following steps that are repeated for each age group.

i) **Age interval (x to x + n):** The period of life between two exact ages. The exact age (x) represents the lower limit of each age interval, beginning with 0 and incrementing to 1, 5, 10, 15 and so on upto 100+ (which is an open interval). The first and second age groups are usually '<1' and '1-4' and the last age group is '100+' whereas the rest of the age groups are of equal size, like '5-9', '10-14', 15-19,....... '95-99'.

ii) **Width of the age interval (n_x) :** This is the number of years in the age interval (x to x+n). Usually, the first value is 1 (interval <1), the second 4 (1-4) and the remaining values are 5 (5-9, 10-14,.......95-99) with the exception of the last value which is again taken as 1 (100+).

iii) **Number of deaths recorded in the age interval (d_x):** This column presents the number of persons dying in that age group during the year corresponding to the life table.

iv) **Number of persons in the age interval (P_x):** This column indicates the number of persons in the age interval during the year corresponding to the life table.

v) **Separation factor ($_na_x$):** This represents the average number of years lived by those who die between ages x and x+n. Although, it is necessary in calculations, this factor is not typically presented as a column of the life table. Each person living in the interval (x to x+n) has lived x completed years plus some fraction of the interval (x to x+n). In a complete life table, a value 0.5 (that is, half of one year) is valid from the age of 5 years. For a simpler calculation, it is assumed that those who die in the 5 year age intervals of a life table live on average 2.5 years. However, remember that the value of the fraction depends on the mortality pattern over the entire interval and not the mortality rate for any single year. In addition, since a large portion of infant deaths occur in the first few weeks of life, this value is much smaller in the <1 and 1-4 age groups.

Similarly, the death rates in the last three groups (namely, 91-94, 95-99, and 100+) are very high. Therefore, the value of the separation factor is small in the age group 91-94 and 95-99. In the last age group (100+) since the death is certain we have taken the separation factor as 1.

Calculation of the separation factor is easy if the date of birth and date of death are available. For the purpose of constructing a life table the separation factor will be given in the table. When they are not, values from model life tables, such as those tabulated by Coale and Demney shown in Table 12.1 can be utilised for and the rest are taken as 0.5 years for every year in the group interval (that is 2.5 in year interval).

Table 12.1 : Separation factors for ages 0 and 1-4

		Separation factor for age <1			Separation factor for ages 1-4		
	Zones	Men	Women	Both sexes	Men	Women	Both sexes
Infant Mortality Rate >0.100	North (1)	0.33	0.35	0.3500	1.558	1.570	1.5700
	East (2)	0.29	0.31	0.3100	1.313	1.324	1.3240
	South (3)	0.33	0.35	0.3500	1.240	1.239	1.2390
	West (4)	0.33	0.35	0.3500	1.352	1.361	1.3610
Infant Mortality Rate <0.100	North (1)	0.0425	0.05	0.0500	1.859	1.733	1.7330
	East (2)	0.0025	0.01	0.0100	1.614	1.487	1.4870
	South (3)	0.0425	0.05	0.0500	1.541	1.402	1.4020
	West (4)	0.0425	0.05	0.0500	1.653	1.524	1.5240

Source: Coale, Ansley J. and Demeny P. (1966) *Regional Model Life Tables and Stable Populations,* Princeton University Press.

Notes: (1) Iceland, Norway and Switzerland; (2) Austria, Czechoslovakia, North-central Italy, Poland and Hungary; (3) South Italy, Portugal and Spain; (4) Rest of the World.

vi) **Central mortality ($_nM_x$) :** This column results from dividing the number of deaths in the age interval x to x+n (column d_x) by the number of people in this age group (column P_x).

$$_nM_x = \frac{d_x}{P_x}$$

vii) **Probability of dying between the ages x and x+n ($_nq_x$):** The probabilities of dying are calculated based on the age-specific mortality rates for each age group. This column is interpreted as the probability of dying between the ages for the person who has survived upto age x. For the last age group of the table, where death is unavoidable, the probability of dying is 1. For other age groups, the calculation is more complicated. The formula for calculation is given below:

$$_nq_x = \frac{n_x \times {_nM_x}}{1+(n_x - {_na_x}) \times {_nM_x}}$$

viii) **Probability of survival between the ages x and x+n ($_np_x$):** It is interpreted as the probability of a person who reaches age x to reach the exact age x+n alive. The formula for calculation is given below:

$$_np_x = 1 - {_nq_x}$$

Since it is $1 - {_nq_x}$, we normally do not show this as a separate column in the life table.

ix) **Survivors to exact age x ($_nl_x$):** This column indicates the number of persons living in the age group x to x+n out of the initial cohort which is usually taken as 100,000.

x) **Deaths between the exact ages x and x+n ($_nd_x$) :** This is calculated using the following formula.

$$_nd_x = {_nl_x} \times {_nq_x}$$

xi) **Number of years lived by the total of the cohort of 100,000 births in the interval x to x+n ($_nL_x$):** Each member of the cohort who survives the interval x to x+n contributes n years to L, while each member who dies in the interval x and x+n contributes the average number of years lived by those who die in this period (that is, the separation factor of deaths ${}_na_x$). ${}_nL_x$ is calculated using the following formula.

$${}_nL_x = n_x \times {}_nl_{x+n} + {}_na_x \times {}_nd_x$$

where, ${}_nl_{x+n} = {}_nl_x \times {}_np_x$ or

$${}_nl_{x+n} = {}_nl_x - {}_nd_x$$

xiii) **Total years lived after exact age x (${}_nT_x$)**: This number is essential for the calculation of life expectancy. It indicates the total number of years lived by the survivor ${}_nl_x$ between the anniversary x and the extinction of the whole generation. The value of the first row of ${}_nT_x$ is the total number of years lived by the cohort until death of its last component.

${}_nT_x$ = Sum of ${}_nL_x$ (from last row of ${}_nL_x$ to the current row of ${}_nL_x$)

xiii) **Life expectancy at age x (${}_ne_x$) :** Among all the indicators provided by the life table, the most widely used is the life expectancy (${}_ne_x$) which represents the average number of years lived by a generation of newborns under given mortality conditions.

Table 12.2 below provides the basic information required for construction of a life table. The data pertains to Indian females in 2000. Let us construct the life table.

Table 12.2 : Basic Information

Age (x)	Number of deaths(d_x)	Number of people(P_x)	n_x	Separation factor (${}_na_x$)
<1	788471	11655599	1	0.1
1-4	430704	44728827	4	1.6
5-9	137870	54725561	5	2.5
10-14	69159	52128201	5	2.5
15-19	100055	48475620	5	2.5
20-24	119360	42745630	5	2.5
25-29	116085	39848328	5	2.5
30-34	109226	35983667	5	2.5
35-39	102540	31934500	5	2.5
40-44	124848	27744053	5	2.5
45-49	150315	23125487	5	2.5
50-54	172910	19212249	5	2.5
55-59	226553	16258203	5	2.5
60-64	288036	13715985	5	2.5
65-69	354148	10813430	5	2.5
70-74	368365	7554310	5	2.5
75-79	335430	4615527	5	2.5
80-84	252665	2332329	5	2.5
85-89	130278	817817	5	2.5
90-94	42440	183658	5	2
95-99	8199	24796	5	2
100+	915	1961	1	+
All ages	4428572	488625738		

Source : World Health Organisation.

Using the formulas given earlier the following life table is constructed.

Table 12.3 : Life Table

Age	n_x	$_na_x$	$_nM_x$	$_nq_x$	$_np_x$	$_nl_x$	$_nd_x$	$_nL_x$	$_nT_x$	$_ne_x$
<1	1	0.1	0.06765	0.06377	0.93623	100000	6376.52	94261.1	6268416	62.6842
1 to 4	4	1.6	0.00963	0.03765	0.96235	93623.5	3524.63	366035	6174155	65.9467
5 to 9	5	2.5	0.00252	0.01252	0.98748	90098.8	1127.83	447675	5808120	64.4639
10 to 14	5	2.5	0.00133	0.00661	0.99339	88971	588.245	443384	5360446	60.2493
15 to 19	5	2.5	0.00206	0.01027	0.98973	88382.8	907.437	439645	4917061	55.6337
20 to 24	5	2.5	0.00279	0.01386	0.98614	87475.3	1212.83	434345	4477416	51.1849
25 to 29	5	2.5	0.00291	0.01446	0.98554	86262.5	1247.4	428194	4043071	46.8694
30 to 34	5	2.5	0.00304	0.01506	0.98494	85015.1	1280.57	421874	3614877	42.5204
35 to 39	5	2.5	0.00321	0.01593	0.98407	83734.5	1333.63	415339	3193003	38.1324
40 to 44	5	2.5	0.0045	0.02225	0.97775	82400.9	1833.39	407421	2777665	33.7092
45 to 49	5	2.5	0.0065	0.03198	0.96802	80567.5	2576.57	396396	2370243	29.4193
50 to 54	5	2.5	0.009	0.04401	0.95599	77990.9	3432.36	381374	1973847	25.3087
55 to 59	5	2.5	0.01393	0.06733	0.93267	74558.6	5019.87	360243	1592474	21.3587
60 to 64	5	2.5	0.021	0.09976	0.90024	69538.7	6937.35	330350	1232230	17.7201
65 to 69	5	2.5	0.03275	0.15136	0.84864	62601.3	9475.39	289318	901880	14.4067
70 to 74	5	2.5	0.04876	0.21732	0.78268	53126	11545.3	236767	612562	11.5304
75 to 79	5	2.5	0.07267	0.3075	0.6925	41580.7	12786.2	175938	375795	9.03774
80 to 84	5	2.5	0.10833	0.42622	0.57378	28794.5	12272.9	113290	199857	6.94081
85 to 89	5	2.5	0.1593	0.56964	0.43036	16521.6	9411.37	59079.6	86567	5.23963
90 to 94	5	2	0.23108	0.68236	0.31764	7110.23	4851.74	20996	27487.4	3.8659
95 to 99	5	2	0.33067	0.82999	0.17001	2258.5	1874.53	5668.9	6491.49	2.87425
100+	1	+	0.46678	1	0	383.969	383.969	822.593	822.593	2.14235

Life expectancy always decreased from the first row of the table to the last row, with the exception of the second row and sometimes the third row (age group/ 5-9), which can be greater than the first row (age group/<1) in countries with high infant mortality. It is generally observed that for a given population, life expectancy is greater in women than in men and overall life expectancy should be approximately between the two. However, in countries where the maternal mortality is high and general living conditions of women are worse, life expectancy among women is lower than men.

12.7 APPLICATIONS OF LIFE TABLES

The life table is widely used in demographic, actuarial, social and health studies. The principal objective of a life table is to calculate life expectancy at birth and at other ages. However, life table provides interesting demographic data which have various applications. In this section you will learn the applications of the life table.

12.7.1 Calculation of Probability of Surviving and Dying

While constructing life table you have learned that $_nq_x$ tells us the *probability of dying* between the two ages (x, x+n) for the person who has survived upto age x. For example, let us consider the row corresponding to age group 30-34 years in Table 12.3. The probability of dying (females) between the ages 30 to 34 year of age who has survived upto 30 years of age is 0.01506 ($_nq_x$). That means out of every 100,000 Indian females who have survived the age of 30 years, 1506 (= 100,000 × 0.01506) will die between the age 30 and 34 years. Secondly, ${}_np_x$ tells us the *probability of living* between the two ages (x, 30-34 years/x+n) for the persons who has survived upto age x. For the age group the probability of survival is 1–0.01506 = 0.98494 (${}_nq_x$). That means out of every 100,000 Indian females who have survived the age of 30 years, 98494 will survive in the age group 30-34 years.

Thirdly, we can calculate the *probability at birth* of a person dying between ages 0-4 years. This is given by the number of original births dying (${}_nd_x$) between the ages 0-4 years, divided by the number of original births (usually 100000). In our example, ${}_nd_x$ = 1281 and the probability is 0.01281(= 1281/100000). This probability tells us that on an average out of every 100,000 female births in India (subject to mortality in 2000), 1281 females will die between the ages 0-4 years.

12.7.2 Uses in Actuarial Science

The life tables have significant applications in actuarial science especially in the field of life assurance. Life tables form the basis for determining the rates of premiums necessary to various amount of life assurance. Life tables provide the actuarial science with a sound foundation, converting the insurance business from a mere gambling in the human lives to the ability to offer well calculated safeguard in the event of death.

Actually, the calculations involved in the fixation of premium amounts in life assurance are very complex, but the underlying principles are simple. Let us consider a few examples.

Example 12.10: According to mortality conditions in India for the year 2000, what annual premium would an Indian female have to pay on a whole life policy worth Rs.100,000 if this life was assured at birth, assuming that the assurance office earns no income on its funds?

Let the premium be Rs. x per annum. Since a female on the average can be expected to live 62.7 years, over her life time she will have paid Rs.x × 62.7 in premiums. This will have to be equal to the value of the policy Rs.100000. Therefore, Rs. x × 62.7=100000 and x = 100000/62.7 = Rs.1594.90.

Example 12.11: In the above example if the policy was taken at the age of 25 years, then find the annual premium.

If the policy was taken at age 25 then the total premiums paid will be Rs. x × 46.9 for 46.9 years expectation of life at 25 years age. Then the annual premium must be x = 100000/46.9 = Rs.2132.20.

Example 12.12: In example 12.10 if the policy is an endowment policy, taken at 30 years of age and payable upto 50 years of age or prior deaths. What is the annual premium to be paid?

If the policy is an endowment policy, taken out say at 30 years payable upto 50 years or prior death, we should proceed on a some what different method. From Table 12.3 we know that 850155 (${}_nl_x$) survivors at age 30 live 1600529.5 (415338.6+407421+396396.1+381373.8 (${}_nL_x$) years between ages of 30 and 50. Consequently, on the average a total of Rs. x × (1600529.5/85015) premiums will be collected and hence the annual premium must be Rs.100000 ÷ 18.83 = Rs. 5310.67.

12.7.3 Other Applications of Life Tables

Apart from its uses in insurance life tables is useful in undertaking comparative analysis of mortality conditions across countries or regions. We discuss some of the applications of life tables below:

i) **Calculation of mortality due to specific causes:** Life tables for different groups of population like sex (male/female), age distribution (different age groups), religion, region are calculated for comparisons. The mortality statistics may prompt us to find the specific causes of deaths in different groups of population.

ii) **Comparison of mortality conditions:** The life expectancy at birth and other ages are the best indices of mortality. These indices considerably vary from place to place and time to time. Over time, in most countries, the life expectancy has increased steadily due to improved health facilities. As you have already learned the female life expectancy is higher than male expectancy except where the female maternal mortality is high. Table 12.4 below explains the life expectancy for males and females in some selected countries.

Table 12.4: Life Expectancy at Birth: Selected Countries - 1999

	Males years	Females years
Australia(a)	76.6	82.0
Canada	75.9	81.4
China	68.3	72.5
France	74.5	82.3
Germany	74.3	80.6
Hong Kong (SAR of China)	76.7	82.2
India	**62.4**	**63.3**
Indonesia	63.9	67.7
Italy	75.2	81.6
Japan	77.3	84.1
Korea, Republic of	70.9	78.4
Netherlands	75.3	80.7
New Zealand	74.8	80.1
Papua New Guinea	55.4	57.3
Singapore	75.2	79.6
United Kingdom	75.0	80.0
United States of America	73.9	79.7

(a) Reference period for Australia is 1998-2000.

Source: Deaths, Australia (3302.0); United Nations Development Programme 2000.

iii) **Population projections:** The life tables have also been used in preparation of population projections by age and sex. That is, in estimating what the size of the population will be at some future date.

12.7.4 Limitations of Life Tables

Life tables are based on demographic data collected from sources such as census and SRS. Therefore, life table estimates have all the disadvantages of any statistical measure based on population censuses and vital records. Data on ages and mortality registration may be incomplete or biased. Infant mortality weighs heavily on life expectancy, which means that under-reporting of this indicator, a habitual fact in many countries, can have an important effect on the results of the tables. Also, important differences in specific age/sex groups with high mortality may be overlooked, since this would have little effect on the overall life expectancy.

Constructing life tables for small populations, at the local or sub-regional level, is generally not recommended, since migratory movements affect the population structure more than at the regional or national levels. In these cases, a very small number of deaths can be obtained, which may produce imprecise calculations of the table's columns.

Check Your Progress 3

Read the life Table given in Table 12.3 in the text. Now interpret the values in the life table by answering the following questions.

1) What is the probability of a female child in India in 2000 would die before reaching 1 year of age?

....

....

2) How many years is a female born in 2000 in India expected to live?

....

....

3) What is the probability of dying of a female between 15 and 20 years of age?

....

....

4) What is the mortality rate between 15 and 20 years of age?

....

....

5) What is the probability that a female reaching 15 years of age reaches 20?

....

....

6) How many additional years is a female between 15 and 20 years of age in 2000 in India expected to live?

....

....

12.8 LET US SUM UP

Vital statistics is mainly concerned with births and deaths. The reliability of vital rates depends upon the effectiveness of the registration system. Incompleteness of registration of births and deaths, in spite of the laws, has made it difficult to give a correct picture of birth and death rates.

Life tables present the mortality and survival experience of a whole population and permit evaluation of its affect on specific groups and over different periods. It is a simple instrument that is easily constructed with data collected routinely.

It is important to keep in mind that life tables are constructed based on population data from censuses and mortality registries. Therefore, the quality of the data affects the validity of the life table.

12.9 KEY WORDS

Cohort : A group of people sharing a common demographic experience who are observed through time. For example, the birth cohort of 2003 is the people born in that year.

Rate of Natural increase : The rate at which a population increases in a given year because of surplus of births over deaths expressed as per 1000 of the population. This excludes migration.

Migration : The movement of people across a specified boundary for the purpose of establishing a new or semi permanent residence.

Mid-year population : It is the average of end-year estimates. For example, the mid-year population of 2003 will be the average of the population as on 31st December 2002 and 31st December 2003.

Infant mortality rate : The number of deaths of infants below one year old per 1000 live births in a given year.

Life expectancy : The average number of additional years a person could expect to live if the current mortality trends continue for the rest of that persons' life. Frequently we use life expectancy at birth.

Actuarial Science : Actuarial Science is concerned with the application of mathematical and statistical methods to finance and insurance, particularly where this relates to the assessment of risks in the long term. In actuarial science we compute the insurance risks and premiums.

Natural Increase : The surplus of births over deaths in a population in a given period of time.

12.10 SOME USEFUL BOOKS

Agarwal, B.L. (1988), *Basic Statistics*, Wiley Eastern Limited, New Delhi.

Ansari, M.A., Gupta, O.P. and Chaudhary, S.C. (1980), *Applied Statistics*, Kedarnath Ram Nath & Co., Meerut.

Benjamin, B.(1959), *Elements of Vital Statistics*, George Allen and Unwin, London.

Chang, C.J.(1980) *Life Tables and Mortality Analysis*, Geneva: World Health Organisation

Karmel, P.H. and M. Polasek, (1986), *Applied Statistics for Economists*, Khosla Publishing House, Delhi.

12.11 ANSWERS OR HINTS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1)

Year	Mid-year population
1950	40.03
1966	51.14
1973	59.46
1985	76.44
1998	97.05

2)

Year	Mid-year population
1954	39.88
1966	50.81
1973	59.07
1985	75.85
1998	97.08

3) The estimated mid-year populations using linear interpolation method are slightly less than the method using compound growth rate method.

4) See Section 12.2 and answer.

5) See Section 12.3 and answer..

Check Your Progress 2

1) The birth rate in rural areas is high because of the lack of awareness among the people on the family planning methods and its need.

2) The death rate in urban areas is low because of the improved health facilities in towns and cities.

3) The infant mortality rate in rural areas is high because of the lack of health facilities in rural areas and malnutrition among mothers.

Check Your Progress 3

1) The probability for a female under 1 to die in India in 2000 (${}_{1}q_{0}$) is 0.06377.

2) The number of years that a female born in 2000 in India expected to live (${}_{1}e_{0}$) is 62.68 years.

3) The probability of a female dying between 15 and 20 years of age group (${}_{5}q_{15}$) is 0.01027.

4) The mortality rate between 15 and 20 years age group (${}_{5}M_{15}$) is 0.00206.

5) The probability that a female in the 15-19 age group reaches 20-24 years age group (${}_{5}q_{15}$) is 0.98973.

6) The life expectancy of a female in the age group 15-20 years in 2000 in India (${}_{15}e_{15}$) is 55.63 years.