Population Studies
Prof. Arun Kumar Sharma
Department of Humanities and Social Sciences
Indian Institute of Technology, Kanpur

Lecture - 11
Techniques of Population Analysis

Friends, now in two lectures we will focus on Techniques of Population Analysis.

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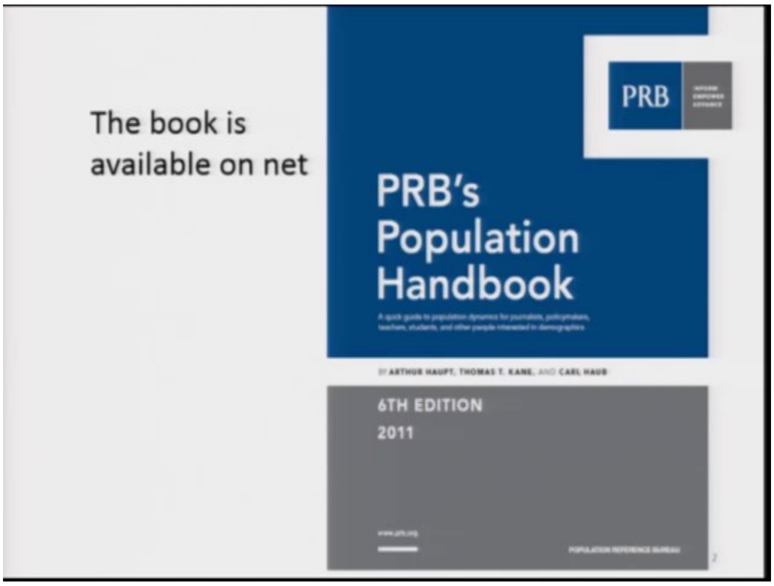

Now, the material that I have taken is from Population Reference Bureau and the technical notes from Population Reference Bureau are available on net, get from there.

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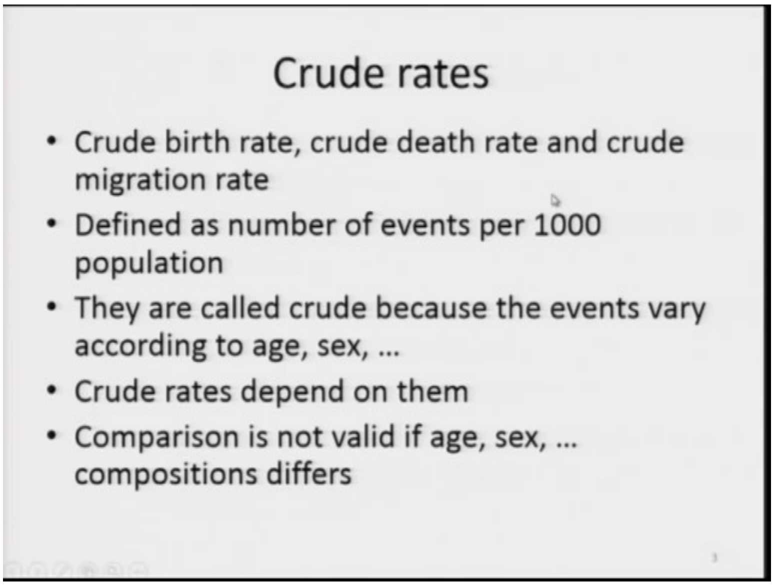

Now, first thing the simplest measures of fertility rate, mortality rate and migration rate etcetera are crude rates, crude birth rate, crude death rate and crude migration rate. These crude rate are defined as number of events per 1000 population; for example, crude birth rate is defined as number of births divided by average population multiplied by 1000. This number of births can be in a given historical time or it can be in a particular year. Similarly, average population or midyear population in case it is for a particular year may refer to a time period or to a particular year and multiplied by 1000.

They are called crude because the events like births, deaths, migration etcetera vary according to age. And that means, the actual birth performance or actual number of deaths or actual number of migrant in a country will depend not only on the crude rate, but also on the age distribution; age distribution of a population. Crude birth rate, crude death rate and crude migration rate are dependent on intensity of; you can call it intensity or fertility mortality.

Like we will later see how they are measured in terms of age specific fertility rates, age specific mortality rates, age specific migration rates. And the crude birth rate, crude death rate and crude migration rate they depend on age specific rates and also on the age distribution of population. Crude rates depend on age, sex and therefore comparison between two populations or comparison of crude birth rate or crude death rate or crude migration rate at two different periods of time in the same population is not valid if age, sex composition of population are different.

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CBR (Crude Birth Rate) by residence, India and bigger States/UTs, 2016

India and bigger States/UTs	Total	Rural	Urban
India	**20.4**	**22.1**	**17.0**
Andhra Pradesh	16.4	16.7	15.8
Assam	21.7	22.8	15.0
Bihar	26.8	27.7	21.1
Chhattisgarh	22.8	24.3	18.1
Delhi	15.5	17.0	15.5
Gujarat	20.1	22.0	17.7
Haryana	20.7	22.0	18.3
Himachal Pradesh	16.0	16.5	10.5
Jammu & Kashmir	15.7	17.4	11.9
Jharkhand	22.9	24.5	18.4
Karnataka	17.6	18.5	16.2
Kerala	14.3	14.3	14.4
Madhya Pradesh	25.1	27.1	19.5
Maharashtra	15.9	16.3	15.5
Odisha	18.6	19.6	13.7
Punjab	14.9	15.6	14.1
Rajasthan	24.3	25.2	21.6
Tamil Nadu	15.0	15.1	15.0
Telangana	17.5	17.8	17.0
Uttar Pradesh	26.2	27.3	22.8
Uttarakhand	16.6	16.8	16.0
West Bengal	15.4	16.9	11.8

Here is a picture of crude birth rate in India; according to residence and state and these figures I have taken from sample registration scheme. Crude birth rate of India as a whole is 20.4 and this is pertaining to year 2016 which means that if you take all the births that took place in India in 2016, divided by average population or midyear population, population on 1st July in India and multiplied by 1000; you will get 20.4.

Rural birth rate is slightly higher than urban birth rate, rural birth rate is 22.1; urban birth rate is 17.0. You can also look at figures of crude birth rate for different states of India. We find that the crude birth rate at the state level comprising both rural and urban population. You know they are highest in case of Bihar and UP; in Bihar it is 26.8, in UP it is 26.2; means on every 1000 people combining both males and females and all age groups; on 1000 people every year 26.8 in Bihar and 26.2 children in Uttar Pradesh are born.

Some of the states where crude birth rate is low are Kerala, then Punjab and West Bengal. In Kerala on the population of 1000 in 2016, only 14.3 children were born. Kerala is a state which has pioneered in fertility and family planning, lowest fertility in terms of crude birth rate, in terms of total fertility rate, in other measures of fertility you find that figures for Kerala are the lowest.

In Kerala in both rural and urban areas crude birth rate is 14.3 or 14.4 almost same; same crude birth rate is there for rural and urban area, but in Bihar rural areas have a crude birth rate of 27.7 and urban areas have a crude birth rate of 21.1. Similarly, in Uttar Pradesh rural areas have 27.3, urban areas are 22.8. So, urban fertility from this point of view using this measure of fertility is lower than the rural fertility, even in high fertility states like Bihar and UP.

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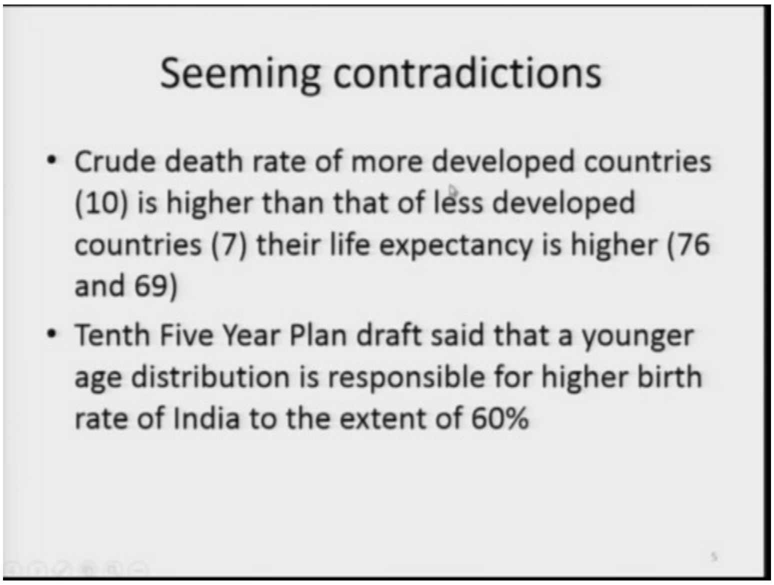

To understand the weakness of crude birth rate or crude death rate, look at the figure that crude death of more developed countries is 10; the latest figure for crude death rate for more developed countries is 10. And the latest figure of crude death rate for less developed countries is 7. Does it mean that the health conditions in developed countries are inferior to health conditions in less developed countries? No, the life expectancy in the developed countries is 76 and in the less developed countries, it is 69.

And therefore, the differences in crude death rate of developed and less developed countries are deceptive. And that is because as I said earlier that crude death rate crude, birth rate crude, migration rate are also dependent on the age and sex distribution of population. Because the intensity of fertility, mortality and migration varies according to age and according to sex and I have been telling this that tenth five year plan said that a younger age distribution is responsible for higher birth rate of India to the extent of 60 percent, which showed the limits of our family planning program.

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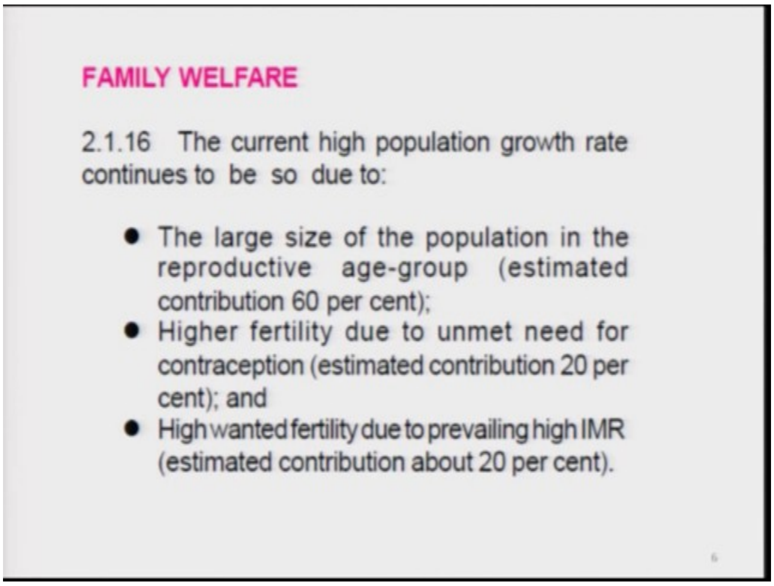

That since 60 percent of the high fertility rate is attributed to age distribution there is not much that you can do. However, in tenth five year plan 20 percent was attributed to unmet needs and unmet needs have declined and 20 percent to infant mortality or high mortality and death mortality has also declined.

Now, regarding family welfare; let us look at the following bullets; the large size of the population in the reproductive age group, estimated contribution 60 percent. This is the quotation from the tenth plan that I am referring to. Higher fertility due to unmet need for contraception, estimated contribution is 20 percent; this is exactly the language the tenth five year plan uses. High wanted fertility due to prevailing high infant mortality rate estimated contribution about 20 percent.

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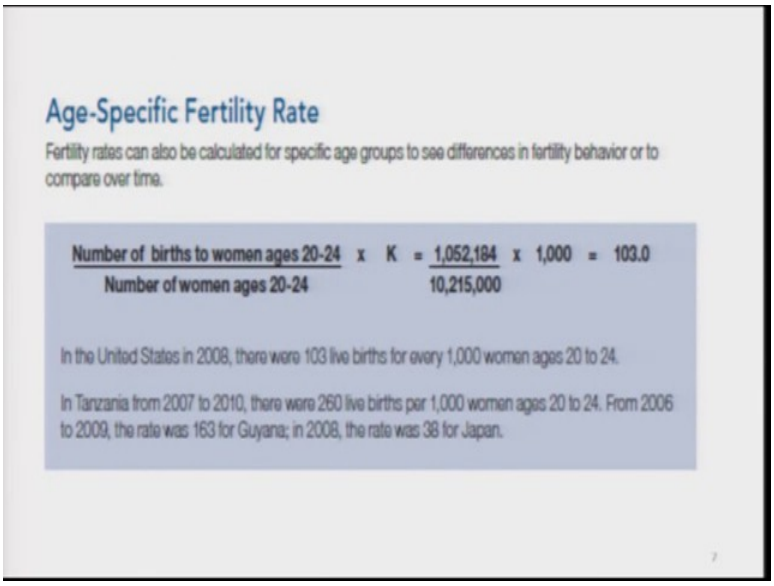

Now, since fertility rates vary according to age; so an attempt is made to estimate fertility according to age and when you do so, then you arrive at age specific fertility rate. So, fertility rates can also be calculated for a specific age groups or ages to see differences in fertility behaviour or to compare them over time. For example, age specific fertility rate in the age group 20 to 24 will be in number of births to women ages 20 to 24 divided by number of women aged 20 to 24. So, here in calculation of age specific fertility rates in both numerator and denominator, we take women in a particular age group.

Age specific fertility rates can be computed for single years means separately at ages 15, 16, 17 up to 49 or in age groups usually for descriptive purposes; we calculate age specific fertility rates in 5 year age groups. So 15 to 19, 20 to 24, 25 to 29 and so on and numerator consists of number of births among women in a particular age group and denominator of number of women in that age group. This refers to midyear or average population of the year goes without saying and K, a constant is usually 1000.

Sometime, for analytical purposes when we use analytical models and like stable population theory; then K can be 1 also. Now, this figure for 20 to 24 in the United States in 2008, there were 103 live births for every 1000 women aged 20 to 24. In Tanzania, from 2007 to 2010; Tanzania is a less developed country; there were 260; more than double; 260 live births per 1000 women aged 20 to 24. From 2006 to 2009, the rate was 163 for Guyana, in 2008; the rate was only 38 for Japan. In age group 20 to 24, Japanese women have such a low fertility that among 1000 women off this age group; only 38 produced a child.

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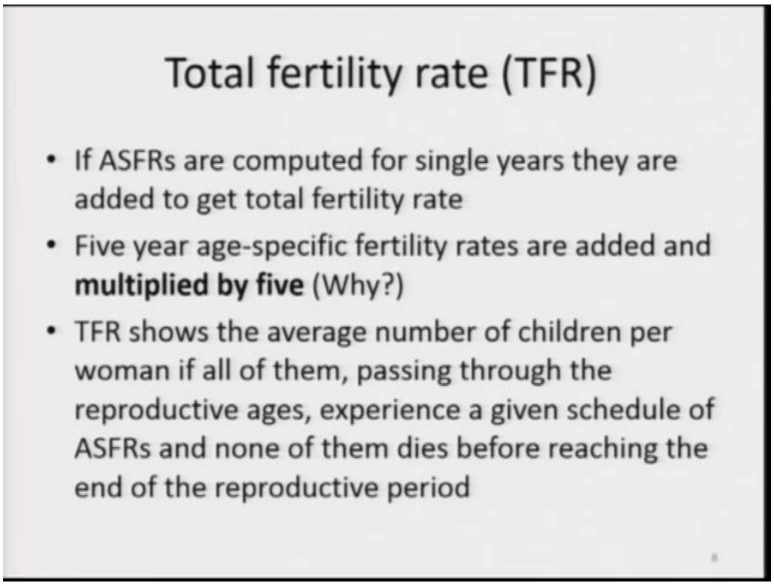

From these age specific fertility rates, we calculate total fertility rate; a measure which I have been using in the previous lectures quite frequently I am saying that we have reached almost the replacement level fertility of 2.1. Our actual fertility total fertility rate is 2.2 and so we are only 0.1 above; the total fertility rate required for replacement. Some surveys, some figures showed 2.3, which is almost same as 2.2.

Now, total if age specific fertility rates are computed for single years; they are added to get total fertility rate. If you add, if you calculate age specific fertility rates for single years and add them up, then you get total fertility rate. If you have age specific fertility rates in 5 year age groups and you add them and multiply by 5, then also you get total fertility rate; why multiply by 5?

Because let us take this 20 to 24; now 20 to 24 age specific fertility rate would be average fertility in 5 year age group 20 to 25; that means, a woman in the age group 20 to 25 will be exposed to this same average fertility for 5 years. And therefore, as we add all the age specific fertility rate for single years to arrive at how many children will be produced between 20 to 25; we have to add this figure 5 times and therefore, we multiply the figures for different age groups by 5.

Imagine that we have age specific fertility rate for 10 years 20 to 30; then this average fertility for 20 to 30 will have to be multiplied by 10 so that we can arrive at a figure of how many children will we produce in the age group 20 to 30. Now, total fertility rate shows the average number of children per women. If all of them passing through the reproductive ages between 15 to 49 experience a given schedule of age specific fertility rates and none of them dies before reaching the end of the reproductive period ok.

This means that imagine; imagine that total fertility rate of India is 2.2 and this can be explained in this way that if there is a group of 1000 women all of whom enter the reproductive age group at 15 together all 1000 women are of age 15 at the same point of time And as time passes they experience age specific fertility rates as given at different age groups, then by the time they all cross 49 or 50 this 49, 50; these kinds of differences create problem.

Actually, one way of writing the age groups is to use age variable as a continuous variable and another to use age as discrete variable you should not confuse. In; in some books and in some papers, you will find age groups as 15 to 19, 20 to 24 in some other papers; so books you will find 15 to 20, 20 to 25 and so on.

. So, when these women; 1000 women cross the reproductive period, at 49 you find the total number of births they have produced is 2000; 2200; that means, on average a woman has produced 2.2 children. Now, in actuality what this line means none of them dies before reaching the end of the reproductive period. This means that we are assuming that no woman who enters the reproductive period at 15 will die before reaching the age 50, but that is too strong an assumption many women will die at different ages between 15 and 49 and total fertility rate does not take that into consideration.

That is why we say that replacement level fertility is 2.1 because in actuality a total fertility rate is 2.1 average number of children per women will be almost 2. .1 will be lost because some women die.

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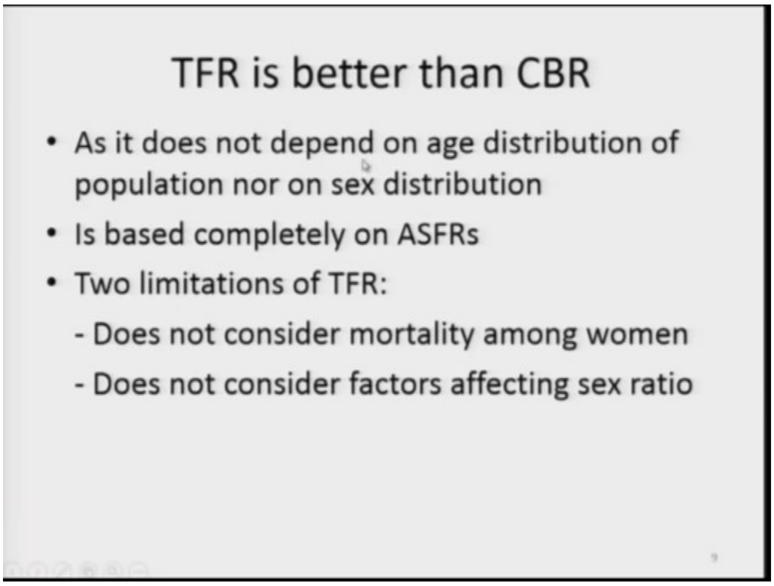

Now, this TFR is better than CBR; it does not depend on age distribution of population nor on sex distribution. We, we simply take the schedule of age specific fertility rates and add all age specific fertility rates after multiplying them by 5; there is no mention of age distribution of population. It is so total fertility rate is based completely on age specific fertility rates yet there are two limitations of total fertility rate.

It does not consider mortality among women and it does not consider factors affecting sex ratio. If you want a major of replacement how many women are replaced by how many daughters; replacement means women are replaced by daughters, then total fertility rate is not adequate for that.

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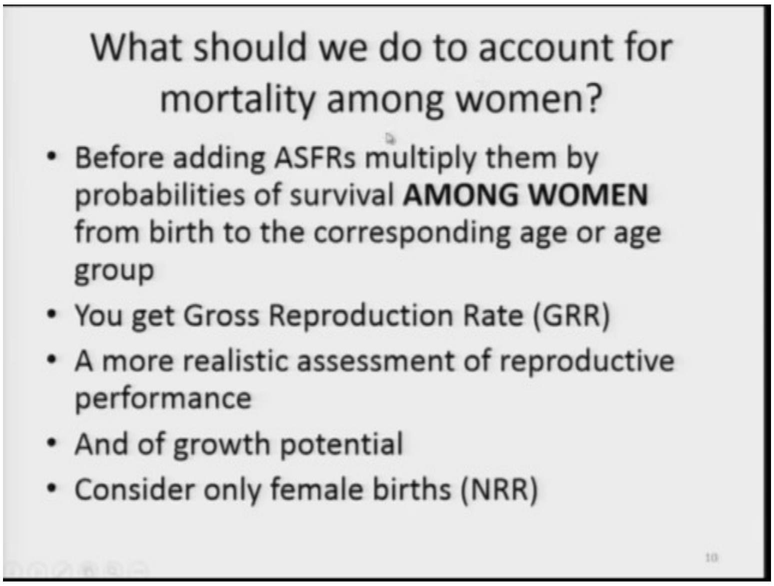

What should we do to account for mortality among women? The answer is that before adding age specific fertility rates multiply them by probabilities of survival among women from birth to corresponding age or age group. These mortality rates and survival rates can be obtained from the life table for the corresponding period.

So, to take care of mortality, you can do this the take probabilities of survival from birth to different age groups from the life table, multiply them by age specific fertility rates and multiply by 5 and add. Now, to arrive at a figure which will show replacement you; you get gross reproduction rate by multiplying total fertility rate by proportion of female births among total births; that takes care of the problem of sex ratio.

This is a more realistic assessment of reproductive performance because number of births is replaced by number of daughters and of growth potential. If you combine the two means if you consider both mortality and sex ratio at birth, then you arrive at the figure of net reproduction rate.

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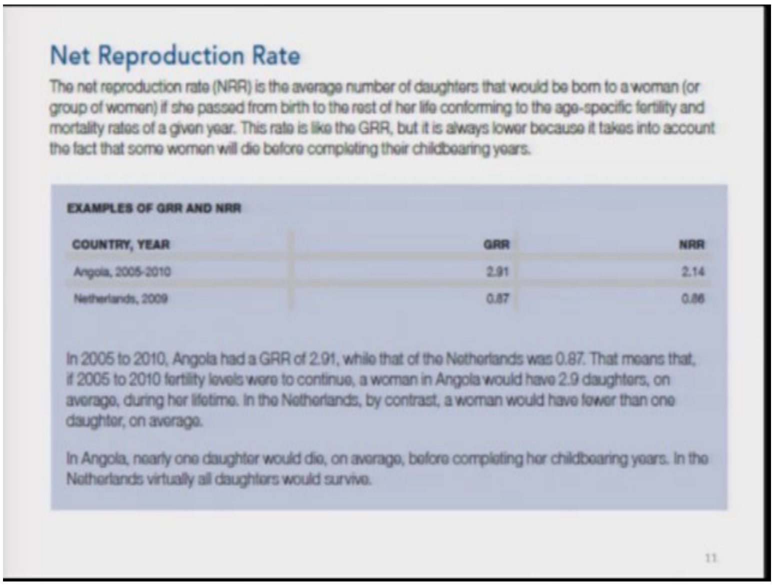

This is net reproduction rate; the net reproduction rate is the average number of daughters that would be born to a woman or a group of women, if she passed from birth to the rest of her life conforming to the age specific fertility and mortality rates of a given year. This rate is like the gross reproduction rate but it is always lower because it takes into account the fact that some women will die before completing their childbearing years. Here are the examples of gross reproduction rate and net reproduction rate- Angola, 2005 to 10 gross reproduction rate was 2.91, net reproduction rate was 2.14.

In Netherlands, gross reproduction rate in 2009 was 0.87 and net reproduction rate was 0.86. You, you noticed that in Netherland 2009, there is not much difference between gross reproduction rate and net reproduction rate. The reason is that the mortality among women in the reproductive ages is rather low. There is more difference in Angola 2005 to 10 between GRR and NRR and that is due to high mortality in the child bearing years. To quote in 2005 to 10 Angola had a GRR of 2.91, while that of the Netherlands was 0.87; that means, that if 2005 to 2010 fertility levels were to continue; a woman in Angola would have 2.9 daughters on average during her lifetime.

In the Netherlands by contrast, a woman would have fewer than one daughter on average this is an example of below replacement fertility. In Angola nearly one daughter would die on average before completing her childbearing years, in the Netherlands virtually all daughters would survive.

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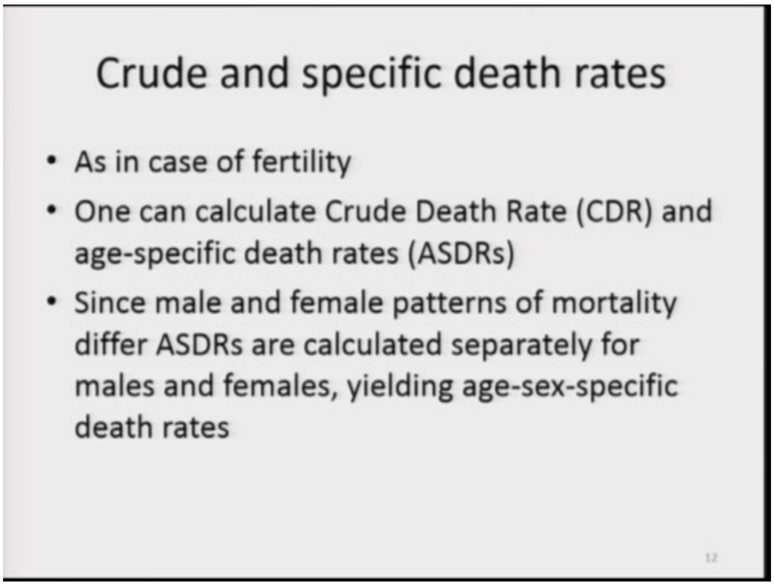

As in case of fertility now you can see that we can calculate crude death rate and also age specific death rates. One can calculate crude death rate and age specific death rates in the same way in which we calculate crude birth rate and age specific fertility rates. Like crude death rate in number of deaths divided by average population into 1000.

And age specific death rate in a particular age group say 15 to 19 would be number of deaths; 15 to 19 divided by average number of persons 15 to 19 multiplied by 1000. Now, worldwide we find that pattern of mortality for males and females is not same. And therefore, age specific death rates are computed separately for males and females. Age specific fertility rates are computed only for women; I have seen some fertility rates computed for men also but in general, we compute age specific fertility rates for women only. Age specific death rates are computed separately for men and women.

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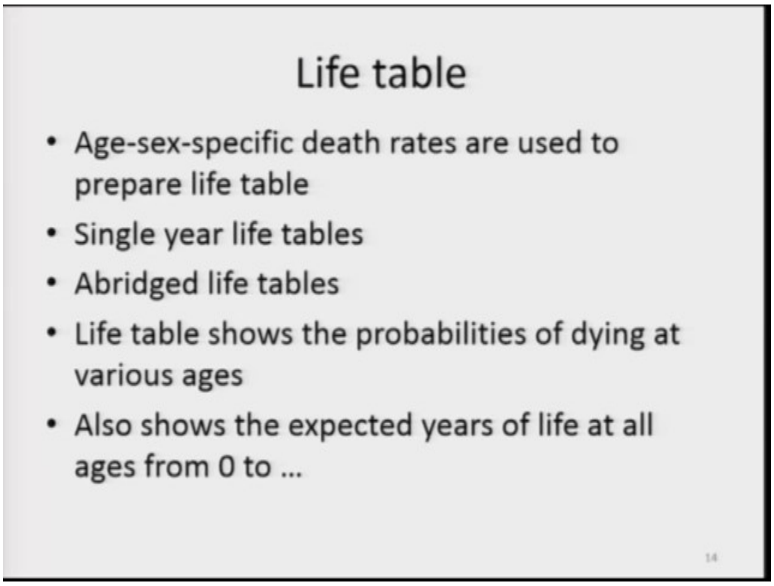

Now, these age specific death rates for men and women are used to prepare life table. Life tables give us probabilities of dying and surviving and life tables can be made for single years; as we can calculate age specific fertility rates and age specific mortality rates for single years and for age groups.

So, life tables can be made for single year age group or single year ages and such life tables are called complete life tables. And when life tables are made for age groups 5 year age groups, 10 year age groups, usually 5 year age groups are used; then the life table are abridged life table, abridged means summary. So, since probability of dying does not change from one age to another at least during adulthood, so, there is no harm if you calculate probabilities of dying or surviving or age specific death rates for 5 years or 10 years; at least in the middle of the age span. This life table produces one very important figure and that is the expected years of life at all ages from 0 to upper age limit of 85 or 90 or in analytical treatment, we write infinity or omega.

Expected years of life at age 0 is most crucial and always we depict health conditions of a country in terms of E 0 or life expectancy at birth. This is a figure which shows that a new born child today is expected to live for so many years; some of them will die immediately, some of them will survive to 1 year, some of them will survive to 50 years, some of them may survive to beyond 100 years also, but on the average they will survive to years equivalent to E 0 0 or life expectancy at birth.

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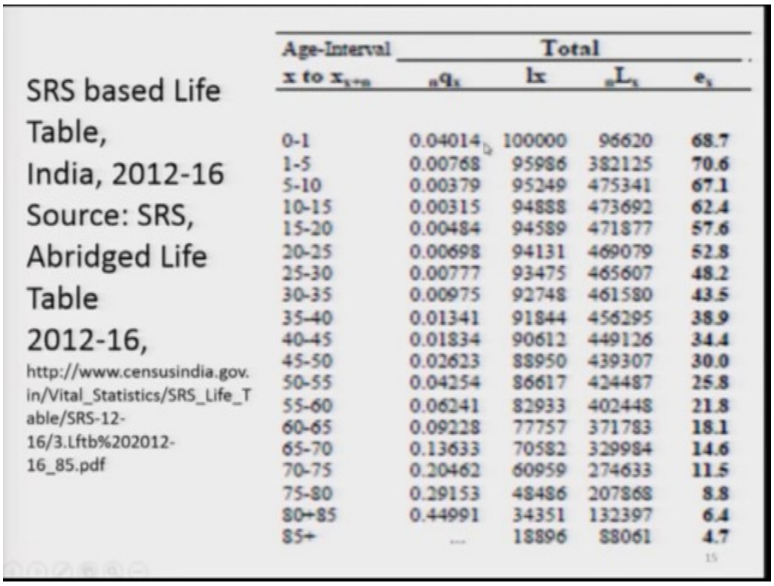
SRS based Life Table, India, 2012-16 Source: SRS, Abridged Life Table 2012-16, http://www.censusindia.gov.in/Vital_Statistics/SRS_Life_Table/SRS-12-16/3.Lftb%202012-16_85.pdf

Age-Interval	Total			
x to x_{x+n}	${}_nq_x$	lx	${}_nL_x$	e_x
0-1	0.04014	100000	96620	**68.7**
1-5	0.00768	95986	382125	**70.6**
5-10	0.00379	95249	475341	**67.1**
10-15	0.00315	94888	473692	**62.4**
15-20	0.00484	94589	471877	**57.6**
20-25	0.00698	94131	469079	**52.8**
25-30	0.00777	93475	465607	**48.2**
30-35	0.00975	92748	461580	**43.5**
35-40	0.01341	91844	456295	**38.9**
40-45	0.01834	90612	449126	**34.4**
45-50	0.02623	88950	439307	**30.0**
50-55	0.04254	86617	424487	**25.8**
55-60	0.06241	82933	402448	**21.8**
60-65	0.09228	77757	371783	**18.1**
65-70	0.13633	70582	329984	**14.6**
70-75	0.20462	60959	274633	**11.5**
75-80	0.29153	48486	207868	**8.8**
80-85	0.44991	34351	132397	**6.4**
85+	...	18896	88061	**4.7**

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This is an example of a life table and this is SRS; Sample Registration Scheme based life table India for 2012 and 16. This is the latest life table for India that I could find and you can get this life table from this source census India dot government in vital statistics SRS life table. Now, look at the columns of this; actually some life tables are more detailed this SRS life table gives us 5 columns and this is abridged; abridged because there are age groups.

Notice that the first 5 year age group 0 to 5 is divided into 0 to 1 and 1 to 5; that is because of special importance of infant mortality; 0 to 1 is infant mortality, 1 to 5 is mortality between 1 and 5 and 0 to 5 would show under five mortality. Then 5 year all 5 year age intervals; this n q x is the probability of dying in the age group means in 0 to 1. Those who have survived to 0 or those who are born at 0, the probability that they will die before reaching 1 is 0.04; that means, 40 per 1000 will die; this is like infant mortality.

Look at the figure 0.009; this means all those who have survived to exact age 30; 9 per 1000 of them; actually, 9.7 per 1000 of them will die before reaching 35; this is how this column is explained. This small lx is the number of persons who will survive to exact ages beginning different intervals. We assume that originally 100000 children are born; so at 0 we have 100000; this is also called the radix of the life table. Then at age 1, the number of survivors is 95986 because others have died between 0 and 1; like this, like 88950; this is the number out of original 100000; 88950 will survive to exact age 45.

And capital L x is something like manpowers in economics this is called person years lived that by these 100000 person; total number of person years lived means totality of time for which they lived in age group 0 to 1 is 96620. Totality of time for which these people 100000 lived in age groups 65 to 70 is 329984; 329984 and the last column is e x life expectancy at birth.

So, this life table tells me that according to age specific death rates prevailing in India in 2012 to 16; a new born baby is expected to live for 68.7 years. Now, you will notice a few interesting things that life expectancy at 1 is higher; at all other ages as time passes as age advanced, life expectancy starts declining. But life expectancy at 1 is higher than life expectancy at 0; that is because life expectancy at any age summarizes the mortality experiences at that age and ages above that and it does not depend at all on mortality experiences of ages prior to that.

So, this 70.6 does not depend on infant mortality; this 70.6 depends on mortality experiences at all ages above 1 ok; this is one interesting thing. Another thing that life expectancy is 68.7 means; a new born baby is expected to live for 68.7, but you if you look at 70 to 75; it shows 11.5 years. Going by 68.7; you may double up the impression that all the people would be dead by 70. No at age 70 those who have reached 70; they are still expected to live for 11.5 years. They will not die immediately, they are expected to live for 11.5; even those who have survived to 85, they are also expected to live for 4.7.

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Life Table, India (females)

e_x	Female			
	$_nq_x$	lx	$_nL_x$	e_x
67.4	0.04137	100000	96584	70.2
69.1	0.00919	95863	381214	72.2
65.5	0.00394	94983	473978	68.9
60.8	0.00295	94608	472345	64.1
56.0	0.00489	94330	470569	59.3
51.2	0.00638	93868	467882	54.6
46.6	0.00668	93270	464809	49.9
42.0	0.00742	92647	461567	45.2
37.5	0.00980	91959	457654	40.6
33.1	0.01376	91057	452318	35.9
28.8	0.01879	89804	445134	31.4
24.7	0.03609	88117	433241	26.9
20.8	0.04957	84937	414798	22.9
17.3	0.08078	80727	388378	18.9
14.0	0.12197	74206	349591	15.3
11.0	0.18581	65155	296650	12.1
8.4	0.26625	53049	231019	9.3
6.1	0.42664	38925	152735	6.7
4.5	...	22318	107661	4.8

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Now, this is life table for female as I said that we make life table separately for males and females and female life expectancy in particular is 70.2. Similarly, here those women who have reached 70; they are still expected to live for 12.1 years like that, 85 plus 4.8.

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$$l_{x+1} = l_x \times q_x$$

$$L_x = \frac{l_x + l_{x+1}}{2}$$

$$q_x = \frac{2Xm_x}{2 + m_x}$$

$$e_x = \frac{T_x}{l_x}$$

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Now, there are some ways of calculating different columns of life table; some you know equations are obvious that persons who survived to exact age x plus 1 will be those who survived 2 x; multiplied by probability of surviving between x and x plus 1. And then we calculate capital L x which is small l x plus small l x plus 1 by 2. Actually, the purpose of this lecture is only to introduce measures of fertility and mortality. So, I am not going into details, but I can tell you that the most crucial of all the equations in preparing a life table is this. What we get from the data from SRS data or other data is m x; m x is age specific death rate at age x. And these age specific death rates are converted into probability of dying by using some formula.

For single year ages; one simple formula is that q x equal to 2 into m x divided by 2 plus m x; assuming that deaths are evenly distributed. Then this T x shows that T x is person years lived at age x; small l x is number of survivors to exact age x. So, T x divided by l x becomes life expectancy.

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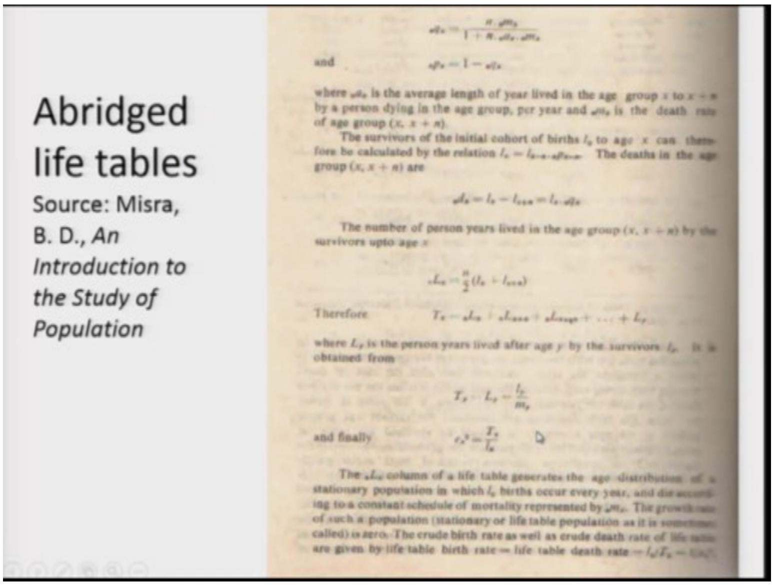

When you make average life tables, then the formula for converting age specific death rates to probability of dying changes to this; this is one of the formulae; there are many formulae and actually mathematically statistics or demography is particularly concerned about how to convert age specific death rates into probabilities of dying and different formulae are used.

But in one simple formula; this n q x maybe expressed as n means width of the age interval into age specific death rate between x and x plus n and divided by 1 plus n into n a x; a new term is introduced into n m x and n a x is the average length of here lived in the age group x to x plus n by a person dying in the age group per year and n m x is the age specific death rate. So, for 5 year age intervals you can take n a x to be 2.5 years assuming that deaths are evenly distributed.

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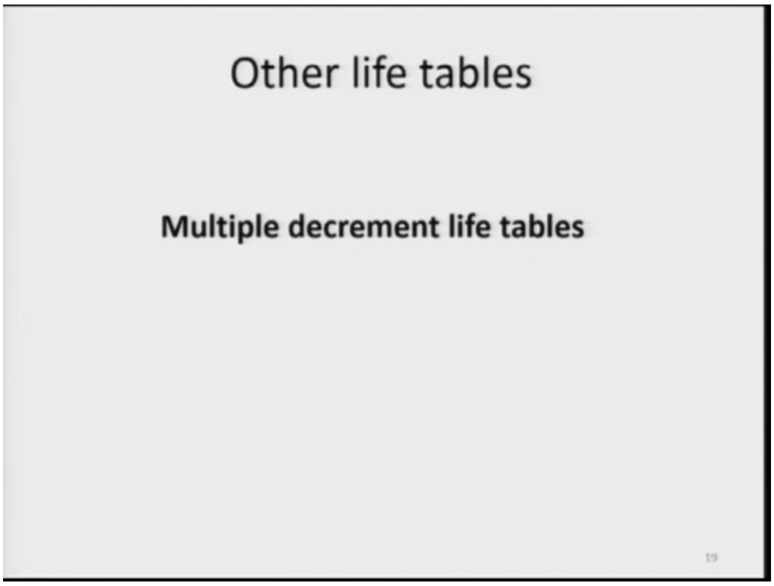

Then there are other life tables multiple decrement life tables.

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Multiple decrement life tables combine two or more forces of decrement; for example, mortality and school dropout. Mortality and working life, mortality and marriage then life tables are also prepared for causes of deaths and disease free life years. And for intrauterine contraceptive device like family planning program as IUCD; as one of the methods we can prepare life tables or use logic like life table for calculating continuation and discontinuation of IUCD by months and for hospital stay.

Here hospital stay would be would mean for how many days; a new patient is going to stay in the hospital which can be calculated from discharge rates per day using the logic of life table. You know sometimes you ask questions like that if a particular cause of death is removed. Suppose removed fully or partly; suppose tuberculosis is eliminated by 50 percent, then what will be the gain in terms of life expectancy?

Suppose a particular cause or say non-communicable diseases as causes of deaths in infancy are removed by 30 percent; what will be its impact on life expectancy? Then that kind of question can be answered by using multiple decrement life tables according to causes of deaths. Similarly, you can know at what age a child is going to dropout and you can combine mortality and dropout data.

Working ages for how many years a person is expected to live, for how many years a person will be in working ages, for how many years a person will work and so on. Similarly, at what age a person will marry and probabilities of survival and dying among married and unmarried persons can be considered separately.

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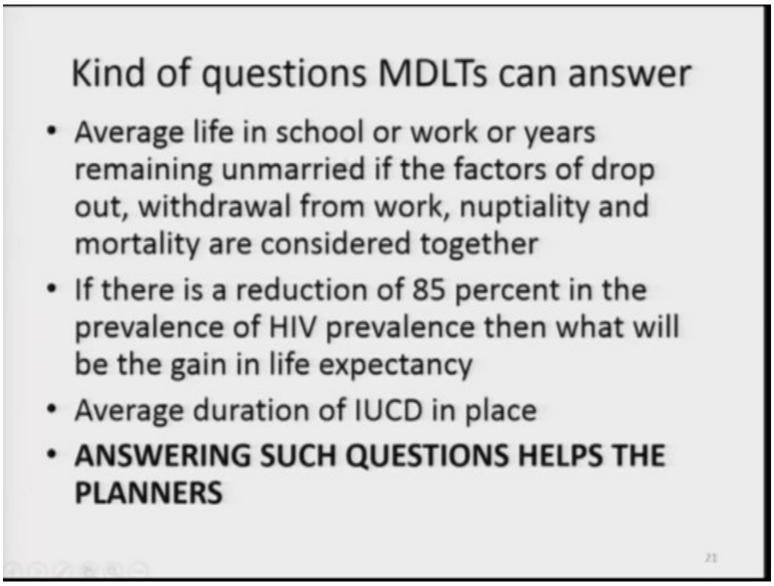

So, these are the questions which multiple decrement life tables can answer. Average life in school or work or years remaining unmarried; if the factors of dropout withdrawal from work nuptiality and mortality are considered together and average duration of IUCD in place answering such questions helps the planners.

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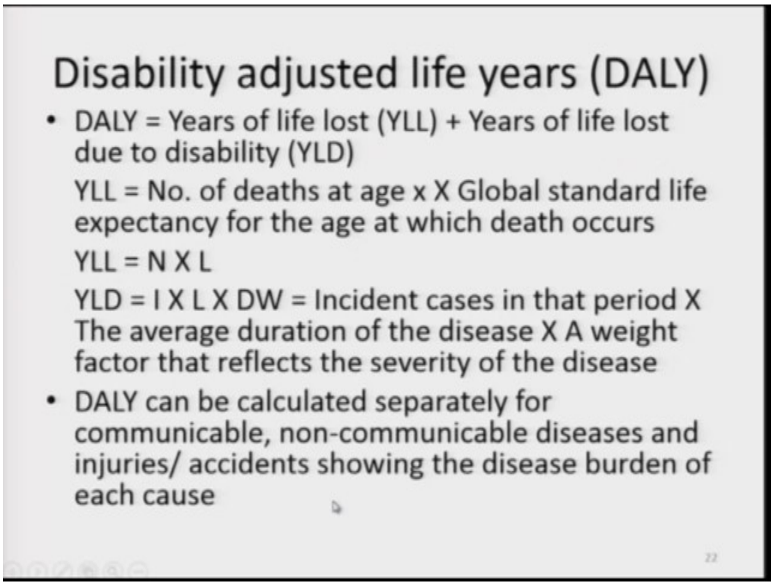

These days we are calculating not simply expected life, but Disability Adjusted Life Years; DALY which is defined as DALY equal to DALY equal to YLL; Years of Life Lost. And this is years of life lost plus years of life lost due to disability and years of life lost is simply number of persons; number of deaths at age x into global standard life expectancy at that age. You know it is like that suppose a person dies at age 15 and life expectancy is at 15 is 65, then 15 multiplied by 65; this is the number of years lost due to death; years of life lost due to deaths.

But similarly years of life can also be lost due to disability, diseases and disability caused by those diseases. These years of life loss due to disability is defined as I into L into DW equal to incident cases in that period. I is incident case, L is the average duration of the disease; some diseases continue for a few a few days only, some diseases for a few months some diseases are disabling for the whole life and DW is a weight that reflect the severity of the disease.

Now, DALY the beauty of DALY is that it can be calculated separately for communicable diseases, non communicable diseases and injuries, accidents showing the disease burden of each cause. And therefore, today whenever measures of mortality are expressed in; in addition to life expectancy at birth and crude death rate, we also show what is DALY; the burden of diseases due to communicable, non-communicable diseases and accidents separately.

Thank you.