Chapter 1

Introduction

1.1 Background

The age structure of any population is influenced by the processes of fertility, mortality and migration. The age distribution remains constant when the levels of fertility, mortality and migration have been constant for a long time (Keilman, 2010). Thus, the changes in age structure of any population depend on three important vital events: fertility, mortality and migration. From various sources, it is evident that over the long period, any population can enhance the survival rates with economic development and advancement in education, medical and public health facilities with better population policies. Mortality is one of the important components affecting the population change, the other two being fertility and migration. Hence, the study of mortality is very important to describe the changing age structure. Along with this, mortality study is demanded other studies like population projection, etc.

Age and sex are the two most important factors leading the detailed analysis of mortality in the field of demography. The relationship between mortality and age is the oldest topic in this area (Preston et al. 2001). Demographers have shown that the mortality varies as a function of age in systematic and predictable ways. The typical variations in mortality with age during the life span are known as “Age-pattern of mortality” and it has drawn considerable attention in the applied field of demography and public health as well. The age pattern of mortality for any population encompasses the history of death and diseases during the previous generations.
In other words, it is the reflection of past levels and trends of illness and consequent recovery or death. Ideally, death should appear at last stage of life when all natural vitality of a human is lost. Under these circumstances, death would tend to amass in the terminal ages of life with only few elisions of early expiries of life at smaller ages. The mortality curve throughout the lifetime of a human population deviates from the above ideal thought. Usually, it is not the old ages only that contribute in most of the deaths but the contribution of early young ages in deaths is also considerable; furthermore no ages can be entirely free from the experience of mortality. The mortality rates as a function of age follow some typical pattern (United Nations, 1955). This mortality pattern follows the U shaped curve when both infant and old age mortality is very high relative to adult mortality. With the improvement in living condition, health infrastructure and medical technology mortality started to shift from earlier to later periods of life that brings the actual pattern of mortality closer to the ideal. Then curve begins to convert in J shape. This phenomenon is observed to be the same for all populations in the world, however, mentioned being controlled by various socio-economic, health and behavioral factors (Heuveline and Clark, 2011).

The infant and childhood mortality rate is considered as a sensitive indicator of the general health status of any population. These two mortality indicators show the inverse correlation with the socioeconomic status of parents. Steady decline in infant and childhood mortality have been observed over time with improvement in the standard of living, sanitary condition and accessibility of health services. Changes in adult mortality are primarily due to the lifestyle diseases and show strong positive association between two (Saikia, 2010). Globally, the death rate at every age over the period has improved, still no finding support about the
betterment of old age mortality in developing countries like India. Therefore, implying that mortality pattern is varying with age.

However, mortality pattern may not vary only by age and sex but also from one region to another. Evidence of sex difference in ill health and mortality can also be found in an attempt of John Graunt in the statistical study of population phenomena first published in 1662. He observed that, although women are more likely to suffer ill health, but mortality rate among females remains lower corresponding to male this may be because of difference in biological construction of male and female. The relative survival rate of the two sexes is a major public health concern in all developing and less developed countries (Lahiri et. al., 2011).

In some societies, where relatively little progress has been made along a continuum of mortality transition, girls and young women experience higher death rate than their male counterparts. It can be thought of as the image for role and status of women within the family and outside the family (Singh, 2002). Countries having very low mortality indicate lower mortality among females than males at all ages. However, in developing world, female disadvantage in mortality has been found in some age groups and especially among young women (Tabutin and Willems, 1998). Sex differential in early age mortality are most prominent in India and other South Asian countries. Also, a wide gap in the sex ratio of age-specific death rate attribute to the sex differential in trends of behavioral and social risk factors such as smoking, alcohol consumption, violence and occupational hazard, etc. (Preston, 1970; Lopez, 1983; Waldron 1985, 1986, and Vallin, 1993).
Thus, the age and sex are the two most important factors leading the detailed analysis of mortality in the field of demography. Along with, there are so many direct and indirect factors influencing the survival chances of any population as a place of residence, level of education, occupation, health infrastructure, etc. A fundamental reason for studying the age pattern of mortality is that it makes possible a statistically sound projection of mortality trends and demographic measurements. The study of mortality age pattern is also very important from the point of view of planning.

1.2 Review of relevant studies

This section reviews some of the studies that are relevant to this research work and divided into two parts. An attempt is made first to explain the approaches to study the mortality age pattern and then to discuss the mortality age pattern studies worldwide and in India.

1.2.1 Approaches for age pattern of mortality

In this section, an effort has been made to read out all approaches for mortality age pattern study. Three approaches can be outlined the age pattern of mortality namely the Analytical (mathematical) approach, Empirical approach and Relational approach (Ewbank et al., 1983).
1.2.1.1 Analytical (mathematical) approach

Usually, analytical approach refers a parametric function \( f(x; a_1, a_2, \ldots, a_n) \) where \( x \) is the age variable and \( a_1, a_2, \ldots, a_n \) are the parameters that provide a close estimate to a class of mortality experience. Early attempts to find a "law of mortality is performed by De Moivre (1725). However in early 19th century Gompertz (1825) discovered the law of mortality that deals with an extensive part of age range (though not including infancy and youth or very old age). According to Gompertz law of mortality, the force of mortality increases with age at a steady exponential rate. He provides a two-parameter formula to represent the force of mortality as mentioned below:

\[
\mu_x = BC^x
\]

The important conclusion of Gompertz model is that the force of mortality \((\mu_x)\) increases in geometric progression with age \(x\). In order to applying this law, problem is not to find a fault with it, but to explain why it works so well. Gompertz himself put forward a possible physiological explanation: that a man's power to avoid death is gradually exhausted as his age increases, congruous with many natural effects.

It was encountered by the Makeham (1860) that Gompertz's law could be improved by adding a constant term that justified as the risk of death from all causes that do not depend on age. At upper ages, fitted value of the constant term in Makeham model is very small, therefore at higher ages, the Gompertz and Makeham law render approximately identical results. However, the applicability of this model was limited to adult ages.
Opperman (1870) suggested a law of mortality that explains only infant and childhood deaths. Opperman’s formula is an intensely flexible means for graduation of childhood mortality in any of the four regional families of Coale Demeny life tables (Hartmann, 1987).

The laws of mortality proposed by Gompertz, Makeham and Opperman are valid only for some specific age group, not for all ages. Therefore, a realistic mathematical model consisting of seven parameters and covering the entire life span was produced by Theile (1872) using decomposition approach. Each term in Theile’s model depicts one of the recognizable aspects of human survival. The first term explains the infant mortality, declining steeply after birth; the second term symbolizes the accident hump and the last term is the Gompertz law which is conquers for a grayer population.

After Theile, Makeham (1890) proposed a four parameter law of mortality. Perks (1932) administered the four parameter mortality model which was a modification over the Gompertz and Makeham law. This law is usually known as the logistic model of mortality. According to Perk, if each unit or member of a population has a mortality law that follows Makeham’s Law $\mu_x = A + BC^x$, but $B$, which is fixed for an individual unit of the population, follows Gamma distribution for the population as whole and Known as Gamma Makeham Model (David, 2006). In the same year, Perks again recommended the five parameters Law of Mortality.
Next model is proposed by Weibull (1951) that draw the failure of technical systems. This model is expressed as $\mu_x = ax^b$. If one consider the distribution of the times to failure of even damage to cells that may lead to death, and suppose that death results when the first such failure occurs, analogy with mortality is noticed. Bras (1976) detected that the logistic function could arise if health is treated as a stochastic process. To justify it, he viewed a cohort that was uniform or homogeneous at birth so that their entire individuals were in the same state of health. He again argues that heterogeneity develops during the life as people travel from one state of health to another and within a given time interval there are probabilities that a person in a given state of health will either remain in the same state, or move to succeeding the state or disappear due to death.

Let us turn to the descriptive "law of mortality" which was proposed by Heligman and Pollard (1980). It depicts the shape of human mortality with an eight-parameter model for all ages. The model can be represented as

$$q_x / (1 - q_x) = A^{x+b} + D \exp \left[ -E(\ln x - \ln F)^2 \right] + GH^x / (1 + GH^x)$$

Where $x$ is age in years, $q_x$ denotes the yearly probabilities of deaths, and $A, B$ up to $H$ is the parameters to be calculated. The curve is continuous and applicable to the entire range of age. The model comprises the three broad age sections each representing the distinct component of mortality. Thus, the first three terms $A, B$ and $C$ manifest the fall in mortality during early childhood, middle three terms $D, E$ and $F$ explains the accident hump among males and maternal mortality plus accident hump among females and ultimately the last two parameters $G$ and $H$ account for the near geometric increase in mortality at the adult ages. Therefore, the
present model justifies the variation in mortality according to three broad age segments of human life.

The idea that $\ln(\mu_x)$ be fitted by a quadratic function of $x$ over limited age ranges was introduced by Coale and Kisker (1990) for the purpose of interpolating $\mu_x$ in the age range 85-110. Below age 85, this model does not give reliable estimates. Kannisto (1992) noticed that the force of mortality ($\mu_x$) at higher ages are very close to one of the simplest forms of the logistic model, in which $\logit(\mu_x)$ is a linear function of age $x$ and this was also used by independently by Himes and associates (1994). The model given by Coale and Kisker (1990) has also been used by Wilmoth et. al. (1995). In their study for estimating $\mu_x$ at age 110 from data which extended above age 85, but again only in this limited range of ages. They observed that the model is purely descriptive and cannot possibly continue to hold indefinitely, to higher and higher ages. If it did, this would imply that the expectation of life is infinite at all ages.

The advantages of the mathematical model are: it is very compact, requires the less number of parameters, easy to generalize. Along with this, the model facilitates the life table construction without imposing the particular age pattern of mortality on the data but hard to fit and if any new source of data by the time will be available, model will not render the good results. Thus, use of mathematical model frequency is very less.
1.2.1.2 Empirical approach

Second approach to describe the age pattern of mortality is “empirical” in which typical patterns are selected from real life tables and are used to generate models by different level of mortality within each identified pattern and known as Model Life Table (MLT). These life tables are comprehensively used for various purposes e.g. smoothing of data, incorporating age-specific mortality patterns, forecasting of mortality rates, and demographic estimation in circumstances where complete vital registration is not in action (Murray et. al, 2003). Using Model life Tables, age-specific mortality rate can be adequately expressed by two or three parameters such as a family to which model belongs and the mortality levels.

The first empirical attempt to construct the model life tables (MLTs) was made by Notestein et. al (1944). However, first set of Model life tables was published by the United Nations (UN) in 1955 (United Nations, 1955). In order to estimate the average age pattern of mortality, a number of regression equations connecting to successive probabilities of death ($q_x$) were constructed (except for the first two age groups $q_0$ and $q_1$, all other age groups considered are 5 years in length) and used for deriving the United Nation Model Life Tables. These are referred as a one-parameter system because it requires only the knowledge of infant mortality rate ($q_0$). These are based on data sets of 158 empirical life tables for each sex that are taken from European countries only.

There were several criticisms of the United Nation’s MLTs; major are highlighted here. First, some of the 158 life tables were doubtful in quality and not accurate particularly at young and old ages. Second, the developing countries, which have a high mortality, are based on a small
number of life tables. In this regard, the most important drawback is that these life tables are one parameter system so inflexible and rigid (Murray et. al, 2003).

Gabriel and Ronen (1958) pointed out that one model frame of reference lead to a broad variation of empirical mortality rates around model estimate at any level, that age-specific mortality could not be estimated reliably on the basis of these tables alone (Anson, 1991). Lederman and Breas (1959) used factor analysis to identify the important factors explaining the variation in mortality pattern of a set of 154 empirical life tables. The study found five factors namely (a) general level of mortality, (b) relation between childhood and adult mortality (c) mortality at older ages (d) mortality under age five, and (e) male-female difference in mortality in the age range 5-70 years. The primary shortcoming of this model is that, it is relatively very complex and second is that the independent variables used in deriving model refers to parameters obtained from both sexes combined. Therefore, user is compelled to agree on the relationship between male and female mortality.

After few years, Lederman (1969) revised his previous work and developed a series of one parameter and two parameter life tables based on regression technique. He proposed new model life tables by generating the logarithm regression equation between probability of dying between ages x and x+5 of the following type

\[
\ln(s_q) = a_o(x) + a_i(x) \cdot \ln(Q)
\]  

for one parameter and,

\[
\ln(s_q) = a_o(x) + a_i(x) \cdot \ln(Q_1) + b2 \cdot \ln(Q_2)
\]  

for two parameter
Where $Q$, $Q_1$ and $Q_2$ are the independent variables and $a_i(x)$ and $b_i(x)$ represent the estimated regression coefficients for age group from $x$ to $x+5$. He estimated the different sets of regression coefficients for each equation based on different independent variables (e.g. $e_0$, $1q_0$, $5q_0$, $15q_0$, $20q_{30}$, $20q_{45}$ and $m_{50+}$) or a pair of variables. It makes easier for user to avoid bias introduced when a model life table is identified to generate the model (Mathew, 1997).

The Coale and Demeny (CD) model life tables were constructed by Coale and Demeny at the office of Population research at Princeton University in year 1966 (Coale and Demeny, 1966). They studied the four different age patterns of mortality (North, South, East, and West) corresponding to the level of mortality by plotting the probability of dying ($nq_x$) against age $x$. For each category a linear regression equation of $nq_x$ and log($nq_x$) on $e_{10}$ was estimated by method of least square. Starting with a broad range of empirical life table, they constructed a general set of model life tables which portrayed the age pattern. Then they examined the $nq_x$ curve of the model pattern at various level of life expectancy at birth ($e_0$) with those of empirical life tables.

The North family is based on nine life tables from Norway, Sweden, and Iceland. This family is characterized by relatively low infant and old age mortality but high adult mortality caused by high incidence of tuberculosis. The south family is derived from the mortality experience of Portugal, Spain, Sicily and Southern Italy. It has a high mortality under age five, low adult mortality and high mortality above age of 65. East families of life tables are generated from 31 central European life tables. This family is characterized by high infant and high old age mortality, relative childhood and adult rates. The West family describes the ‘average’
mortality pattern and frequently used. The West models were a residual collection after the above three families and based on 130 life tables which are considered to be accurate but did not fit any of the three groups (Coale, et. al., 1983).

Strict standards of accuracy imposed in the construction of Coale-Demeny model life tables limited the number of non-European countries represented. They may not be appropriate for studying mortality pattern in developing countries and elsewhere cause of death and disease pattern are probably substantially different. For this reason, the Coale–Demeny tables may not cover patterns of mortality existing in the modern developing world (Murray et. al, 2003).

The United Nation’s (1982) made an attempt to overcome some of the limitations of Coale-Demeny (1966) model life table by producing the new set of model life table known as New United Nations model life table. The new life tables were based on the experience of developing countries (like India, Iran, Kuwait, Israel, and Tunisia; countries of central and Latin America and South-East Asia). A total of 72 life tables were used; 36 of male and 36 of females. They divided the life tables into five groups say Latin American, Chilean, South Asian, Far Eastern and General pattern.

Latin American is characterized as a group having high infant and child mortality due to excess diarrheal and parasitic diseases. Adult mortality is high due to the accident and old age mortality is low because of low mortality from cardiovascular diseases. Chilean family has high infant mortality, mainly due to deaths from respiratory disease. The South Asian pattern has a high mortality under 15 and over 55, but relatively low mortality at adult ages.
Nevertheless, the Far Eastern family is characterized as very high mortality at old ages, perhaps due to tuberculosis. The General pattern is very much similar to Coale-Demeny West region. A revised version of Coale and Demeny's MLTs were again published in the year 1983 (Coale and Demeny, 1983).

Clark et. al, (2009) also developed a new "component model of mortality." Clark suggested that it was possible to represent the shape of a specific pattern of mortality with a linear combination of a small number of age based components. These components must contain all information to explain age pattern of mortality. These model life tables are of two-parameter systems where one parameter is to specify family and another for level of mortality within each family.

Wilmoth et. al, (2009) proposed a new set of model life tables using data from 1800 life tables of Human Mortality Database (HMD). In this model, they considered the relationship between adult and child mortality using a set of quadratic regression in addition to some constant value.

\[
\log (m_x) = a_x + b_x * h + c_x * h^2 + v_x * k \quad \text{where } h = \log \left( q_x \right)
\]

In the above equation, quadratic component describes the relationship between the mortality at age x and under five mortality. \(v_x\) shows the shape of the deviation with age and \(k\) represents the magnitude of this deviation. This study does not fit where age pattern of mortality reflects
severe armed conflict and also when HIV/AIDS is a significant cause of death. For further details of the above two new models, one may refer the article by Heuveline and Clark (2011). Wilmoth et. al, (2011) modified the earlier developed new system of model life tables for betterment of quality and transparency of such assessments. In it, they fitted the flexible two-dimensional mortality models using the Human Mortality Database. For providing the full life table, this model required only the information on child mortality or child and adult mortality; however, the second parameter is optional. This new model outperforms the existing empirical models. The model advised here act as a ground for a new and good system of mortality estimation with incomplete data set for any population.

The shortcoming common to all the empirical models is their dependence on the type of data used. The database upon which they were built excludes a significant proportion of possible mortality schedules (Murray et.al, 2003) as they rely on some specific mortality rate (\( q_0 \) or \( q_5 \) or \( q_{15} \)). Although, the United Nations set of model life tables attempted to address this issue, but there were some serious flaws on life table construction as well as criteria of acceptance.

1.2.1.3 Relational Approach

Age pattern of mortality may also be represented by a third approach popularly known as "Relational models" at first suggested by Brass (1971). These tables were mainly used for simulation purpose and mortality projection and comprise the characteristics of both empirical and mathematical approach and provide a greater degree of flexibility than the empirical model. In this movement, the general shape of the survivorship functions is captured through
the mortality standard while the parameters help to capture variation from the standard (Murray et al., 2003).

Brass developed a set of relational life tables based on the assumption that two distinct age-patterns of mortality can be related to each other by a linear transformation of the logit of their respective survivorship probabilities, \( l(x) \) and said that one may fit the model using any standard. The model can be represented as

\[
Y(x) = \alpha + \beta \star Y_s(x)
\]

Where

\[
Y(x) = \logit\left(1_x\right) = 0.5\star\left[(1-1_x)/1_x\right]
\]

and

\[
Y_s(x) = \logit\left(1_x^s\right) = 0.5\star\left[(1-1_x^s)/1_x^s\right]
\]

Empirically, it is observed that \( \alpha \) ranges between -1.5 to 1.0 and \( \beta \) lies between 0.6 to 1.6. In applying the Brass logit system, the main problem is to select the standard life table. Any standard can be taken that affirm the average pattern of mortality. Two standards are in common use named as General and African pattern. However, there is nothing special about these two life tables; it is quite possible to use any other standard according to study (Newell, 1988). The Brass model does not fit well at extreme ages.

Later, Brass himself suggested a method for generating a set of standards by adding the multiples of two sets of age-specific deviation to his general pattern. With this, Zaba (1979) extended the Brass model and added two more parameters (\( \psi \) and \( \chi \)) and defined as four parameter Brass logit model. The former has the effect of curving the mortality pattern of the standard in the same direction at old and young ages while the later tends to twist the pattern
of mortality in the opposite direction at each end of age range. Because of this, the two parameters interact and, therefore, do not have separate interpretation as $\alpha$ and $\beta$. This is a major disadvantage of this system. Also, deviation from linearity seems to be prominent when the observed mortality of a population is far from that of standard and therefore, mortality age pattern is not fully described by the logit model (Zaba 1979; Ewbank et al., 1983).

This observation leads the World Health Organization (WHO) to modify the Brass logit system of life tables based on the principle of Brass’s original logit model life table construction (Murray et al., 2003). The choice of the logit system was based on a careful comparative evaluation of the logit and Coale-Demeny systems. In this model, the basic comment is that the deviations from linearity follow the same specific regularity. This symmetry can be modeled in relation to the change in mortality between standard and observed life tables. This model investigated the relationship between under five mortality ($5q_0$) and adult mortality ($45q_{15}$) using the properties of the logit scale. This method is a modification over the Brass logit system as Brass considered completely linear relationship between two survivorship functions which may not be true in all situations. Based on above, Murray and associates examined the relation between two survivors using the following equation:

$$\Gamma(1_x) = \alpha + \beta \Gamma'(1_x)$$

Where,

$$\Gamma(1_x) = \logit(1_x) + \gamma\left[1 - \frac{\logit(1_x)}{\logit(1_x^*)}\right] + \theta\left[1 - \left(\frac{\logit(1_{15})}{\logit(1_{15}^*)}\right)\right]$$
Where \( l_5, l_{50}, l_{60} \) are the number of survivors at age 5 and 60 for observed and standard population respectively, \( \gamma \) and \( \theta \) are the age-specific parameters and \( \Gamma (l_5) \) denotes the transformed value of \( l_5 \).

In 2004, a set of life tables popularly known as "INDEPTH" (International Network of field sites with continuous Demographic Evaluation of Populations and their Health in developing countries) life tables were also published by INDEPTH (2004). These tables are prepared for African countries as the mortality situation prevailing there is completely different from the others and also the existing model life tables fail to provide satisfactory results. This study uses only the information on infant mortality rates and under five mortality rates as input. It was based on Brass logit system. This model fits only for single decrement model and low HIV prevalence countries in Sub-Saharan Africa. It is suitable for generating baseline mortality estimates for multi-decrement models (Gordon, 2008).

Given all these different set of model life tables, it is often difficult to choose which one to use. The choice is not helped by the fact that no strict rule can be given. The one that fits best must always be the most flexible to let real features and irregularities through, but which is sufficiently robust to be unaffected by errors in data.
1.2.2 Age Patterns of Mortality Studies in India

In the previous section, thesis discussed all the available approaches to study the age pattern of mortality globally. In the present section, dissertation will talk about the studies looking for age patterns of the mortality situation in India. In India, mortality was high during the 19th century and started declining from the beginning of the 20th century. The changes in population growth are the attributable to the relatively rapid reduction in mortality rather than fertility and migration. In the post-independence period, rapid reduction in mortality at younger ages has been the dominant contributory factors in the improvement in life expectancy at birth (Navaneetham and Krishnakumar, 2011). Many factors have acted as an accelerator in the reduction of mortality at younger ages and middle ages. Maternal and child health interventions, improvement in education, development in medical technology, etc. have diminished the occurrence and prevalence of diseases and infection.

India has made an appreciable progress in improving its overall health condition since the beginning of the century. In India, over the decades, it is observed that age pattern of mortality is heading to a plateau shape from the early U shaped curve in adult age groups and mortality rates have increased in oldest of old. India’s life expectancy at birth has been increased from 49.7 years (1970-75) to 68 years (2002-06). Infant mortality rates have been approximately half from 105 to 55 during the same period. In high mortality era, infant mortality contributed as the greatest part of total mortality. The high death rates during this period were detected because of diseases like plague and influenza epidemic and famine. Also, there is a wide variation in mortality pattern among the states of India. The substantial decline in mortality
after 1920s has drawn the attention of several demographer as well as researchers (Navaneetham and Krishnakumar, 2011).

Das (1974) studied the age pattern of mortality using the National Sample Survey data on the basis of the age pattern of mortality of England and Wales for the calendar period 1891-1965. For this study, he assumed that the improvement in mortality at different ages in the developing countries would occur in such a way that mortality at adjacent age group would follow the pattern observed in developed countries at corresponding level of mortality. In the used method, Das reveals that it is possible to obtain abridged life table for rural-urban areas separately for the regions for which internal migration are not available.

Parasuraman (1984) in a study found that the logit systems of life tables could more realistically represent the mortality pattern in India rather than the Coale-Demeny life tables. Ram (1984) in one of his research work discovered that Weibull function can be used to settle the Brass estimates, and the parameters can be used to study the age pattern of mortality for infant and child. Bhatt (1987) examined the levels, trends and patterns of mortality for India and its major states. In this study, he stated that life expectancy at birth increased about 14 years between 1951-61 and 1971-81. During the period, the crude birth rate have been fallen by 20 percent. He also observed that slowest reduction in mortality was in Odisha (earlier known as Orissa). Also, when he was insuring the quality of SRS data, experienced that ASDRs show substantially lower levels of mortality in the age span 10-45 than do model life tables, but higher mortality outside this span.
Roy and Lahiri (1987) pointed out that for male and particularly for females, mortality age pattern looked like South Asian pattern of United Nation’s model life tables and also the South pattern of the Coale-Demeny life tables. Parasuraman (1990) also tested the applicability of various mortality models to the Indian age patterns of mortality. According to the relationship between adult mortality and young age mortality for males and females, she breaks all the major states of India into two groups. In the first group of states (Bihar, Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh) the relationship agrees either the South pattern in the Coale and Demeny life tables or the South Asian pattern from the United Nations life table for developing countries, whereas second group (Andhra Pradesh, Karnataka, Kerala, Maharashtra, Odisha, Tamil Nadu and West Bengal) do not follow any of the above mentioned patterns.

Malaker and Roy (1990) made an attempt to reconstruct the life tables for India from 1901-11 to 1971-81 and to project the mortality for the decades 1981-91 and 1991-2001 by adopting Brass relational model life table system. To check the consistency in the model, they tested the value of e0 for both sexes and encountered that e0 for females in 1991-2001 was in accordance with the values estimated by United Nation’s and another international source. However, for males e0 gained from this model is observed to be much higher compared to females.

Chaurasia (1992) made an effort to show the regional variations in the age pattern of mortality in India by using the Heligman Pollard mortality model. In this study, he experienced that the age pattern of mortality in different parts of the country has an important difference in male
as well as female populations. The study also reveals that even within the same clusters significant differences in the age pattern of mortality of different sexes preserves.

Navneetham (1993a) also agreed with Bhatt and Navaneetham (1991) on the observation that mortality has been declined more rapidly among the children less than 15 years during 1980s. Mortality analysis by age manifests that the child mortality declined substantially for both male and female during period 1970-86, and this may be attributed to the implementation of Maternal and Child Health program in India.

Bhatt (2004) make an attempt to modify the Brass logit model. Unlike Murray et. al. (2003), rather than advising to add any additional parameters, he suggested to estimate the model deviation from linearity using the available information on child mortality and adult mortality for the population and empirically derived the standard pattern of deviations. The proposed generalized logit model is opted because it is more flexible than the Gompertz model. Also, it is found working very well when the observed is far from standard as compared to WHO methodology.

Another study by Chaurasia (2010) concludes that the rate of improvement in the probability of survival in the first five years of life has been decelerated over time and, in females, this probability has decreased instead of increasing in recent years. He also argues that there has been a substantial gradual decline in the entropy of life tables, especially in female life tables. It implies that the shift in concentration of deaths towards the grayer population has been
diminished significantly. Saikia (2010) attempted to examine the level, trends and patterns of adult mortality in India. Her study revealed that the epidemiological transition is not uniform throughout the country.

Therefore, the above section is primarily concerned with the approaches and studies related to age patterns of mortality and highlighted the significances and drawbacks of the various approaches.

1.3 Need for the study

India is a country with second largest population and having high infant mortality rate (IMR), under five mortality rates (U5MR) and maternal mortality ratio (MMR) (50 per 1000; 64 per 1000; 212 per 100,000 respectively (ORGI, 2011b). Along with, socio-cultural dissimilarity, diverse geographic features within the country also play an important role in demographic consequences such as fertility and mortality. Due to the geographical and socio-economic discordance of the country, the health and development scenario has never been uniform. The regional heterogeneity in health condition of states is appeared both in inter as well as intra-district variation and leads the different mortality condition among districts. But, to understand the district level differentials in mortality, very few information are available.

In India, districts are the basic unit of administration for all development and planning process. It leads the growing demand of district level indicators of health, development and education, etc. Millennium Development Goals (MDGs) set by the Government of India (GOI) also necessitates for precise estimates of the development indicators such as life expectancy at
birth (LEB), infant mortality rate and under five mortality rates at state level as well as below the state level either to examine geographic inequalities in mortality or to monitor the effects of public health policies to inform local strategies or to prepare long-term population projections for smaller area.

However, it is seen from the foregoing discussion that very few studies have made an attempt to study the mortality age patterns at district level. Therefore, in this context there is growing need, observed in many government and non-government organizations to develop the proper mortality databases, to examine the differentials among districts and to provide mortality indicators for effective monitoring and evaluation of various human development programs including health, demographic changes at the district and lower levels.

The Census of India, conducted decennially, provides useful demographic information at district and lower administrative level. There are many other important sources, such as the Civil Registration System (CRS), Sample Registration System (SRS), National Family Health Survey (NFHS), District Level Household and Facility Survey (DLHS) and the Annual Health Survey (AHS), providing the below state level (such as region and district) information on mortality. But each sources have their own limitation and quality of reported data is also not up to the mark. As it is earlier stated, that mortality varies by age and sex and can be studied by more deeply through age pattern. Along with, at district level only the information on infant and childhood mortality are available; age-specific death rates (ASDRs), adult and old age mortality rates are not available. Moreover, the available data of mortality are fragmentary that suffers deficiency and inconsistencies at district level.
Thus, to meet the challenges for district level or below state level mortality estimates, there is a need to adopt an indirect approach to produce all information at one place. It is found that life table method is simplest and well-designed way to achieve this. Also, available literature retrieved that studies dealing with district level mortality age patterns are very few in India; previous studies have focused only on national and state level. Very few serious attempts have been made to develop the mortality database at district level. Therefore, the present study highlighted the differentials in the age pattern of mortality by means of developing life tables at district level and will be helpful in achieving the administrative and research needs of public health agencies at below state level.

**1.4 Objectives of the study**

The main intention of the present thesis is to accomplish the systematic analysis of age pattern of mortality in India by means of developing Model life table system. Furthermore, the focus of the present study is on studying recent district level differentials in age patterns of mortality by age and sex. Specific objectives of the study are:

1. To explore the age patterns of mortality in Indian life tables and their differentials by residence, gender and major states.
2. To study the changes in age patterns of mortality across gender and major states over the period 1970-2010.
3. To develop a model life table system for India and states.
4. To derive the model based life tables by sex for districts of India for Census year 2001.
1.5 Organization of the Thesis

The thesis is organized into seven chapters and can be divided into three parts. The first part deals with the introduction, review of relevant studies, setting of the problem, purpose and scope of the study. These are covered in chapter 1 and 2. The second section of the thesis describes levels and trends of the age patterns of mortality at national and sub-national level, changing pattern and variation of mortality across sex and place of residence. Chapter 3 and 4 is devoted to this aspect. An important part of the thesis is examined in the last section and kept in chapter 5 and 6. In this section, dissertation attempted to develop a model life table system for India and states and further to construct the district level life tables. The final chapter 7 gives an overview, conclusion and limitation of the study. However, description of each chapter is given below:

Chapter 1: Introduction

Chapter 2: Data and Methods

Chapter 3: Levels, Trends and Patterns of Mortality in India

Chapter 4: Changing Age Patterns of Mortality in India

Chapter 5: New Model life tables for India and States

Chapter 6: District Level Model Based Abridged Life Tables for India

Chapter 7: Summary and Conclusions