CHAPTER - III

MORTALITY
3.1 A Mortality analysis through estimation of life expectancy from vital rates at District level

3.1.1. Introduction

It has become a crucial point to note that for successful progress of any developmental programme, the planning has to be decentralised and to be initiated from the most feasible smallest administrative units like districts. But for any such initiative, we need an adequate knowledge of the population dynamics of each district in the country, as well as its social, cultural and economic characteristics, at the sub-national levels (i.e. state and district levels in India). Apart from the size, growth and some other salient characteristics of the population, there is virtually no knowledge of fertility, mortality and migration of the district level population. Among these factors mortality condition of a population shows the health status of the society to count the manpower of the country.

The indices of mortality which are frequently used in the analysis of mortality are the crude death rate (CDR), age specific death rate, infant mortality rate and the life expectancy at birth. Each of them is having its own importance and biases. As for instance, it we take the first index CDR
into consideration, it is most easy and short-cut method for measuring the overall mortality situation in a population but is quite misleading if it is used to make comparisons between the mortality in two populations having different age-sex composition. The age specific death rates though provide more detailed information on mortality at various age sectors but are unsuitable for measuring overall mortality situation. Though infant mortality rate is one of the sensitive indicators of the socio-economic status of a population but it does not provide the total mortality experience of the given population. The life expectancy at birth has unique advantage that it gives cumulative effect of mortality over entire length from birth and is independent of age structure of the actual population and is not affected much by the minor fluctuations in mortality at particular ages.

A few methods for the estimation of expectation of life at birth ($e^0_0$) are developed in the recent past by several researchers. They are categorised as direct and indirect. Direct methods deal with the age distribution of the total count of the population as well as of deaths for the period under study. The indirect methods described in the Manual of United Nations[199] require either the age distributions of the population under study at two different points of time or the age distribution of the population at a particular point of time together with the knowledge of natural increase. These
methods assume that the population under study is close to migration.

But some researchers have made different approaches for estimating $e_0$ by using vital rates. Bourgeois-Pichat[18] argued through a graphical analysis that for a quasi-stable population, the life expectancy may be estimated on the basis of crude vital rates. Researchers like Mc. Cann [118] developed a method for estimation of the life expectancies from crude vital rate by using the principle of stable population. Though this method is derived on the basis of stable population theory but it can be applicable for quasi stable population and the population with slow decline in fertility. This method is also based on the assumption that the population under study is closed to migration but the main advantage of this method is that it does not require the age distribution of the population which is frequently found to be affected by age misreporting. Also Keyfitz and Flieger[93] found a variety of demographic measures like life expectancy by using intrinsic vital rates. In this regard, Nanda Lal[96] made an attempt to estimate the life expectancies for some of the Indian states from their crude vital rates during the period 1973-75 by applying the method developed by Mc. Cann [118]. In consultation with above methodologies, it will be appropriate to estimate the life expectancies at birth at district levels of the state of Orissa. In fact apart from the size, growth
and some other characteristics of the population there is hardly any knowledge of fertility and mortality at a district level population. Local surveys in reference to the above purpose practically do not exist or are insufficient for a demographically undeveloped state like Orissa. So the only alternative available to researchers for this state for analysis at district level seems to be census, which needs to be explored for estimating the vital rates. The 1981 census data of India gives some more information and opportunity for the estimation of the level of vital rates up to the district level. However the nature of data on children ever born and children surviving is also of a poor quality and cannot facilitate reliable estimates of fertility and mortality as noted by several distinguished demographers like Pathak and Ram[141] and Holla[78]. The choice is now fallen on the age distribution of the population for indirect estimation of vital rates. All the information available at the state level can also be generated at district level by adopting indirect procedure developed by Pathak and et al. [143]. At the district level the age distribution of population can be extensively used to estimate fertility. All the methods employed for estimating fertility from the age distribution of population requires the knowledge about level and age pattern of mortality for the population. Also it requires data of population in 0-4, 0-9, and 0-14 age groups, where it is seen that there occurs a significant under estimation. The precise
extent of omission in the 0-4 age group where there is a large omission of children can never be estimated. So all these methods fail to take stock of these error situations which requires a detailed calculation based on the life table methodology and an alternative leading method in this direction has been proposed by Pathak and et al. [143] which deals with estimating the vital rates at sub-national level without a prior knowledge of mortality levels and the use of model life tables. We thought it as an opportunity to use these indirect methods developed by Pathak for estimating the vital rates of different districts of the state of Orissa, where the quality of data is very poor. In this case the estimate seems to be closer to any estimate of the vital rates developed by any sound demographic mechanism like that of vital registration system. The growth rates developed by Pathak's method are best used by us for estimating the life expectancy at the district level of the state of Orissa.

Pathak's method virtually dispensed with the computation of the growth rates except CDR. In absence of any existing indirect method we have estimated CDR by using stable population theory.

3.1.2 Methodology

Lotka's[108] well known age distribution of population following the laws of stability is given by
\[ C(x) = b e^{-rx} p(x), \quad 0 \leq x \leq \infty \]  

...... (3.1.2.1)

Where,

- **C(x):** Proportion of persons of exact age \( x \)
- **b:** Intrinsic birth rate per person.
- **r:** Intrinsic rate of natural increase per person.
- **p(x):** Proportion of persons who survive from birth to exact age \( x \) in a stable population.

If \( \mu(x) \) is the death rate at exact age \( x \) (or the instantaneous force of mortality at age \( x \)), the crude death rate \( d \) in a stable population is given by

\[
d = b \int_0^\infty p(x) \mu(x) e^{-rx} \, dx
\]

or

\[
\frac{d}{b} = \int_0^\infty d(x) e^{-rx} \, dx
\]

...... (3.1.2.2)

Where, \( d(x) \), (the product \( p(x) \mu(x) \)) is the proportion of deaths at exact age \( x \) in the stable population. Alternately, the term \( d(x)dx \) denotes the probability that a person who survive up to age \( x \) and die within an infinitesimal interval \((x, x+dx)\). Further more, we know that

\[
\int_0^\infty d(x) \, dx = 1
\]

...... (3.1.2.3)

According to the definition of moment generating function (m.g.f) of a probability distribution, the m.g.f. of \( d(x) \) about the origin is given by
\[ M_x(t) = \int_0^\infty e^{tx} d(x) \cdot dx \] \hspace{1cm} (3.1.2.4)

Again, the cumulant generating function, \( k_j(t) \), of the probability distribution of age at death, can be expressed as a convergent series in powers of \( t \), i.e.

\[ K_x(t) = \log_\phi M_x(t) \]
\[ = k_1 t + k_2 \frac{t^2}{2!} + k_3 \frac{t^3}{3!} + \ldots + k_m \frac{t^m}{m!} \ldots \]
\hspace{1cm} (3.1.2.5)

where, \( k_i \ 1=1,2, \ldots m \), are the first, second, \ldots mth cumulants of age at death. Now putting \( t = -\tau \) in (3.1.2.5), we find that

\[ \log_\phi \int_0^\infty e^{-\tau x} d(x) \cdot dx = -k_1 \tau + k_2 \frac{\tau^2}{2!} - k_3 \frac{\tau^3}{3!} + \ldots \]
\hspace{1cm} (3.1.2.6)

Now taking logarithm of both sides of (3.1.2.2) and comparing with (3.1.2.6) we find

\[ \log d - \log b = -k_1 \tau + k_2 \frac{\tau^2}{2!} - k_3 \frac{\tau^3}{3!} + \ldots \]
\hspace{1cm} (3.1.2.7)

Since the first, second and third cumulants are equivalent to mean, variance and third central moment, the equation (3.1.2.7) can be expressed as

\[ \log d - \log b = \mu \tau - \frac{\tau^2}{2!} \sigma^2 + \frac{\tau^3}{3!} \mu_3 - \frac{\tau^4}{4!} \mu_4 + \ldots \]
\hspace{1cm} (3.1.2.8)

Where,

\( \mu \) is the mean age at death in a stable population and is equivalent to \( e_0^0 \), life expectation at birth. \( \sigma^2 \) is the variance.
of age at death, \( u_j \) is the third central moment of age at
death and \( k_4, k_5, \ldots \) are the 4th, 5th... cumulants of age at
death.

Rearranging the term in (3.1.2.8), we may find

\[
e_0' = \mu = \frac{\log b - \log d}{r} + r \left( \frac{\sigma^2}{2!} - \frac{r^2}{3!} + \frac{r^3 k_4}{4!} \right) \ldots \ldots
\]

or, \( e_0' = e_0 + R_0 \) \ldots \ldots (3.1.2.9)

where,

\[
e_0' = \frac{1}{r} (\log b - \log d) \ldots \ldots (3.1.2.10)
\]

represents the first order approximation of \( e_0' \) and depends
only on the crude vital rates,

and \( R_0 = \frac{\sigma^2}{2!} - \frac{r^2 k_4}{3!} + \frac{r^3 k_5}{4!} - \frac{r^4 k_6}{5!} + \ldots \ldots \ldots (3.1.2.11) \)

is a correcting factor containing the higher order cumulants
from the second onwards of the age distribution of deaths and
hence the value of \( R_0 \) depends not only on the rate of natural
increase (\( r \)) but also on the structure of mortality. From
(3.1.2.9) and (3.1.2.11) one may easily find that the
contribution of \( R_0 \) and \( e_0'^0 \) is quite significant even when the
value of \( r \) is very small. However, it may be noted that the
contribution of \( R_0 \) is relatively weak for the very low and
very high values of life expectancy because the life table
deaths are concentrated at the youngest and oldest ages of
life for the very low and very high values of \( e_0'^0 \) respectively.
Now, our problem is how to estimate the value of the correction factor $R_0$. Since the expression for $R_0$ in (3.1.2.9) contains higher order cumulants of age distribution of deaths, its value cannot be obtained unless the age distribution of deaths is known in advance. But such information is not available to us, now the only information at our disposal becomes the crude vital rates.

However, Mc.Cann [118] proposed an indirect technique for estimating the value of $R_0$. While plotting the value of $R_0$ against $e_0'$ obtained by using Coale- Demeny [36] model stable population for male based on West model, Mc. Cann [118] found a parabolic relationship between $e_0'$ and $R_0$. The input values for $e_0'$ and $R_0$ were obtained from the crude vital rates and life expectancies corresponding to the West (male) stable population through (3.1.2.9) and (3.1.2.10). The graphic representation between $e_0'$ and $R_0$ indicates that the correction factor $R_0$ can be estimated quite closely from $e_0'$ through a non-linear function and Mc. Cann [118] found that a quadratic regression of $R_0$ and $e_0'$ provides a satisfactory approximation. On the basis of Coale- Demeny [36] model stable population for both sexes, Mc. Cann fitted eight least squares quadratic equations for $R_0$ and $e_0'$, one for each sex and for each family mortality. The coefficients of the parametric equations of $R_0$ and $e_0'$ i.e., $R_0 = A + B e_0' + C (e_0')^2$, for the four Coale Demeny families of mortality along with the values of
multiple correlation coefficients \( R^2 \) and standard error \( S.E \) of the estimates are given Table 3.1(3). The author further found that in every case, the fitting is quite strong and the implied accuracy for estimating life expectancy is also quite satisfactory. After a good deal of discussion on the effects of error in vital rates, Mc. Cann[118] found that errors in death rates affect the estimate of life expectancy more seriously than those in birth rates in general. Moreover, the effects of errors in birth rates on the estimate of life expectancy are negligibly small when the birth rate is at intermediate or high level. While discussing the effects of departure from the assumption of stability through a simulation experiment based on the actual probable experience of transitional population report in a publication of United Nations[200] the author found the method to provide reasonable good results for the population satisfying the condition of quasi-stability. Further more, the author found that a moderate decline in fertility will not affect the estimate seriously.

An analysis of real populations for which Keyfitz and Flieger[93] table a variety of demographic measures including life expectancy and intrinsic vital rates, shows that West model equations provide reasonable good approximation for \( e_0^0 \) even when the true mortality pattern is other than that of the West model.
For estimation of vital rates Pathak et al. (143) suggested the following methodology for the estimation of birth rates without the use of model life tables.

\[
C.B.R. = \frac{C(5).\exp(2.5 \times r)}{5.S(2)} \quad \ldots \quad (3.1.2.12)
\]

Where C.B.R. is the birth rate of a census year, C(5) is the proportion of child population below the age of 5 years, \( r \) is the population growth rate during the last 5 years, which may be the inter census growth rate.

\[
S(2) = \frac{\text{Children surviving to the women of age group 20-24}}{\text{Children ever born to the woman of age group 20-24}}
\]

At the district level, the growth rate (\( r \)) has been adjusted as follows.

\[
R_d = R_s \times \frac{\text{CWR}_d}{\text{CWR}_s}
\]

When \( R_d \) = the growth rate for district in the state.
\( R_s \) = The growth rate of the state.
\( \text{CWR}_d \) = Child-Woman ratio for district defined as ratio of number of children in age group (0-4) to the Women of age group 15-49.
\( \text{CWR}_s \) = Child woman ratio of state defined as above.

After finding the CBR for total (Males and females combined), the same for either sexes can be calculated.
Male birth rate = Total birth rate × \[\frac{S.R.B.}{1+S.R.B.}\] × \[\frac{1+S.R}{S.R}\]

Female birth rate = Total birth rate × \[\frac{1+S.R}{1+S.R.B}\]

Where,

S.R. = Overall sex ratio in the population (Males per females).

S.R.B. = Sex ratio at birth (Males per females); the values of S.R.B. may be taken as 1.05 for this study.

For finding total death rate we may apply stable population theory as given in Mishra [121a]. Hence the death rate = (birth rate - growth rate)

After finding the values of total death rate, Sex specific (Male and Female) death rate can be found out by taking the value of sex ratio at death. Here the value has been taken as 1.02 which has been found out from the SRS data of last ten years.

The values of the combined \(e_0\) can be obtained from the male and female \(e_0\) by using sex ratio at birth.

\[e_0\] (combined) = \[\frac{e_0\] (male) × S.R.B + \(e_0\] (females)\]}{1+S.R.B.}\]

This study has been carried out for the thirteen undivided districts of the state of Orissa for the year 1981. The relevant data has been collected from the census reports of 1981 and other Government of India Publications.
3.1.3 Results and Discussion

Here the crude birth rates have been estimated at the state and as well as at the district level for the year 1981 by adopting an indirect methodology proposed by Patnaik and *et al.* However, it may be mentioned that the estimate of vital rates at the district level may not be as reliable as the estimates of the state and national level because of possibility of presence of error in the 0-4 age-group of the population. The consistency of the estimate across the districts is of greater importance. The district level estimates are given in Table 3.1(1). It may be observed from Table 3.1(1) that the CBR varies from 29.86 for Mayurbhanj district to 36.53 for the district of Balasore. It is also observed that about five districts i.e. Sundarqarh, Mayurbhanj, Bolangir, Kalahandi and Koraput possess CBR below the value of state level CBR (32.81). For the study the sex-specific birth rates have been estimated from the total birth rate by using sex ratio and sex ratio at birth. Similarly the age-specific crude death rates can be estimated at the district level through the same process. It may be observed that Phulbani district shows the highest CBR (16.70), which stands to be followed by the district Balasore (16.13). The district Sambalpur has shown the lowest CDR (12.30). So the values of CDR at the state and district level are shown to be
under estimated because these are derived from CBR, which may suffer from under counting of data in the 0-4 age group.

The life expectancies of either sexes of different districts have been estimated by taking the vital rates and using the West model for the correction factor developed by Coale and Demeny for stable population. The values of $e_0^0$ are presented in Table 3.1(2). It is clear that Sambalpur has the highest $e_0^0$ (57.52 & 58.03) for either sexes among all the districts. The second highest $e_0^0$ goes to Mayurbhanj. The districts Phulbani (48.56) and Balasore (49.59) have shown the lowest $e_0^0$ for males and females respectively among all the districts of the state. For males it may be observed that about six districts of the state i.e. Keonjhar, Balasore, Phulbani, Koraput, Ganjam and Puri have $e_0^0$ below the value of the state (52.70). Similarly, in case of females the districts Keonjhar, Balasore, Cuttack, Dhenkanal, Phulbani, Koraput, Ganjam and Puri have $e_0^0$ below the state level (53.43). The values of $e_0^0$ for all the districts, except Sundergarh, show favourable to females than males. It may be noted that the life table for Western Zone (Maharastra and Gujrat) 1961-71 constructed by Registrar General of India also shows this type of sex differentials in $e_0^0$. The study conducted by Nanda Lal [96] for the period 1973-75 showed that Orissa along with other states like Andhra Pradesh, Assam, Himachal Pradesh, Kerala and Tamilnadu, have $e_0^0$ favourable for females than males. The results of our study may be substantiated by the
research conducted by Nanda Lal. Also Table 3.1(2) presents the values of $e_0^0$ combinely for both the sexes. It is observed that Sambalpur and Phulbani exhibit the highest (57.77) and lowest (49.17) values of $e_0^0$ respectively. Only five districts, i.e. Sambalpur, Sundargarh, Mayurbhanj, Bolangir and Kalahandi, bear $e_0^0$ above the state level (53.06) and two districts i.e. Cuttack and Dhenkanal, stand at the same level of the state (53.06).

From the above observations it is found that the districts having $e_0^0$ for both sexes, below the state level consists of both categories of districts i.e. tribal and non tribals. The reason behind the lower values of $e_0^0$ than the state level of three tribal districts i.e. Keonjhar, Phulbani and Koraput may be due to the fact that most of the people of these districts seem to be illiterate and poor. Also malnutrition and lack of health facilities, frequently aggravate the suffering of people by diseases resulting in a substantial lower life expectancy. Some reasons for low $e_0^0$ of three coastal districts i.e. Balasore, Ganjam and Puri, may be over population, poor sanitation and swamping atmospheric environment. Detailed analysis to various socio-cultural practices prevailing in the districts may give more insight into the sex differentials in $e_0^0$. 
Table 3.1(1) Estimated Crude Vital Rates for males and females of various districts of Orissa, 1981.

<table>
<thead>
<tr>
<th>Districts</th>
<th>Crude Birth Rates</th>
<th>Crude Death Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
</tr>
<tr>
<td>1. Sambalpur</td>
<td>30.00</td>
<td>30.28</td>
</tr>
<tr>
<td>2. Sundergarh</td>
<td>32.58</td>
<td>32.28</td>
</tr>
<tr>
<td>3. Keonjhar</td>
<td>33.61</td>
<td>34.78</td>
</tr>
<tr>
<td>4. Nayurbhanj</td>
<td>29.86</td>
<td>30.44</td>
</tr>
<tr>
<td>7. Dhenkanal</td>
<td>33.97</td>
<td>34.13</td>
</tr>
<tr>
<td>8. Phulbani</td>
<td>33.84</td>
<td>34.67</td>
</tr>
<tr>
<td>9. Bolangir</td>
<td>32.40</td>
<td>33.03</td>
</tr>
<tr>
<td>11. Koraput</td>
<td>32.11</td>
<td>32.73</td>
</tr>
<tr>
<td>12. Ganjam</td>
<td>33.82</td>
<td>35.18</td>
</tr>
<tr>
<td>13. Puri</td>
<td>33.22</td>
<td>33.38</td>
</tr>
<tr>
<td>Orissa</td>
<td>32.81</td>
<td>33.28</td>
</tr>
</tbody>
</table>
Table 3.1(2) Estimates of $e_0^o$ of either Sexes of districts of Orissa, 1981.

<table>
<thead>
<tr>
<th>Districts</th>
<th>Male</th>
<th>Female</th>
<th>Combined $e_0^o$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sambalpur</td>
<td>57.52</td>
<td>58.03</td>
<td>57.77</td>
</tr>
<tr>
<td>Sundergarh</td>
<td>55.31</td>
<td>54.49</td>
<td>54.91</td>
</tr>
<tr>
<td>Keonjhar</td>
<td>50.84</td>
<td>54.84</td>
<td>51.82</td>
</tr>
<tr>
<td>Mayurbhanj</td>
<td>56.22</td>
<td>56.92</td>
<td>56.56</td>
</tr>
<tr>
<td>Balasore</td>
<td>48.97</td>
<td>49.59</td>
<td>49.27</td>
</tr>
<tr>
<td>Cuttack</td>
<td>53.06</td>
<td>53.33</td>
<td>53.19</td>
</tr>
<tr>
<td>Dhenkanal</td>
<td>52.99</td>
<td>53.20</td>
<td>53.09</td>
</tr>
<tr>
<td>Phulbani</td>
<td>48.56</td>
<td>49.81</td>
<td>49.17</td>
</tr>
<tr>
<td>Bolangir</td>
<td>53.30</td>
<td>54.46</td>
<td>53.87</td>
</tr>
<tr>
<td>Kalahandi</td>
<td>53.13</td>
<td>54.61</td>
<td>53.85</td>
</tr>
<tr>
<td>Koraput</td>
<td>51.74</td>
<td>52.77</td>
<td>52.24</td>
</tr>
<tr>
<td>Ganjam</td>
<td>50.61</td>
<td>52.96</td>
<td>51.76</td>
</tr>
<tr>
<td>Puri</td>
<td>52.01</td>
<td>51.93</td>
<td>51.97</td>
</tr>
<tr>
<td>Orissa</td>
<td>52.70</td>
<td>53.43</td>
<td>53.06</td>
</tr>
</tbody>
</table>
Table 3.1(3) Coefficients of the parametric equation $R_0=A+Be_0^1+Ce_0^2$ and multiple correlation coefficient ($R^2$).

<table>
<thead>
<tr>
<th>Models type</th>
<th>Sex</th>
<th>Coefficient</th>
<th>$R^2$</th>
<th>S.E.E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>West</td>
<td>Male</td>
<td>-13.54</td>
<td>23.193</td>
<td>-0.2959</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>-8.87</td>
<td>23.476</td>
<td>-0.2923</td>
</tr>
<tr>
<td>North</td>
<td>Male</td>
<td>-23.00</td>
<td>23.981</td>
<td>-0.2951</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>24.08</td>
<td>24.563</td>
<td>-0.298</td>
</tr>
<tr>
<td>East</td>
<td>Male</td>
<td>52.47</td>
<td>22.586</td>
<td>-0.3012</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>35.56</td>
<td>22.998</td>
<td>-0.2912</td>
</tr>
<tr>
<td>South</td>
<td>Male</td>
<td>4.15</td>
<td>24.177</td>
<td>-0.2986</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2.54</td>
<td>24.805</td>
<td>-0.2954</td>
</tr>
</tbody>
</table>

S.E.E : Standard error of estimates.
Table 3.1(4) Different values for estimation of Birth rates and Death rates for the year 1981.

<table>
<thead>
<tr>
<th>Si. No.</th>
<th>Districts</th>
<th>Growth rates of population</th>
<th>Child woman Ratio (per thousand)</th>
<th>Proportion of child population below 5 years</th>
<th>Proportion of children surviving to children ever born</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sambalour</td>
<td>0.0177</td>
<td>482</td>
<td>0.12/1</td>
<td>0.8858</td>
</tr>
<tr>
<td>2.</td>
<td>Sundergarh</td>
<td>0.0193</td>
<td>527</td>
<td>0.1381</td>
<td>0.8897</td>
</tr>
<tr>
<td>3.</td>
<td>Keonihar</td>
<td>0.0187</td>
<td>509</td>
<td>0.1376</td>
<td>0.8580</td>
</tr>
<tr>
<td>4.</td>
<td>Mayurbhanj</td>
<td>0.0168</td>
<td>457</td>
<td>0.1275</td>
<td>0.8904</td>
</tr>
<tr>
<td>5.</td>
<td>Balasore</td>
<td>0.0204</td>
<td>556</td>
<td>0.1410</td>
<td>0.8124</td>
</tr>
<tr>
<td>6.</td>
<td>Cuttack</td>
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3.2 An Optimization technique for estimating Infant Mortality Rate

3.2.1 Introduction

Infant mortality rate is a measure of mortality among infants. The importance of studying IMR is obvious because of several reasons. At first, the IMR is one of the most sensitive indicators of the medical and health facilities in a population. Secondly, it measures the mortality in that segment of the population where it is extremely high and to which the expectation of life at birth is very sensitive. Thirdly, any reduction in mortality in general affects the IMR to a greater extent and it is through this that it influences the age distribution.

In usual computation of IMR we take great amount of care to identify all deaths in the first year of life—its break-up by hours and days after the birth. Equal effort goes into finding the base population (birth) so that the rate is as reliable as possible. But we completely ignore the fact that IMR also depends on the age of the mother and parity of birth. We have separate information on age and parity distributions of births and deaths but very little is done to combine the two sets of information to form the IMR.

If we try to include both the level of IMR and its pattern by age of the mothers in the conventional approach,
then obviously, the sample has to be selected differently, and also it has to include much bigger-factors which are not always under our control. Finance and general objective of the sample survey may limit our options severely. In this situation, and even with existing data, the LP approach allows as the option to impose the age pattern and other restrictions on the estimated IMR.

Brass et al.\cite{22} and Fenny\cite{53} have given ingenious methods for the estimation of IMR from the children ever born and surviving. But Mukerji\cite{125} has initiated a different approach for estimating IMR by each age group at the national level adopting a multi-objective approach (Swanson\cite{189}).

Orissa behaves differently in demographic character. In spite of several programmes launched by the government, the state Orissa takes the highest position of IMR (114 per thousand) in India and there is no such downward tendency of this rate. The estimation of IMR lacks accuracy because it is a cumulative value being affected by several factors. Direct method does not consider all the conditions operating on mortality system of the infants simultaneously. It ignores the effect of the age of mother, parity of birth, fertility status of the married woman and number of births and deaths at each age group on IMR. Also, there may be less use of hard data in direct method. It is difficult to find out IMR at a micro-
level with higher level of accuracy. So it becomes a need to develop an indirect technique for estimating IMR at the state level satisfying all the restrictions simultaneously operating on the IMR system. For this a Linear Goal Programming (Ignizio [81] & Swanson [189]) has been designed to estimate the IMR by age of women in Orissa such that in the specified time period the rates by age of women follow a given pattern and at the same time the overall IMR lies in a given range.

3.2.2 Methodology

Let $\beta_i \forall i = 1, \ldots, 6$ and $\delta_i \forall i = 1, \ldots, 6$ be the proportion of children born and lost to women of completed fertility in the ages 15-19, 40-44 in the five-year period preceding the date of survey. $\gamma_i \forall i = 1, \ldots, 3$ be the proportion of children born to the married women in the age group 15-19, 25-29. $k_i \forall i = 1, \ldots, 6$ are the pooled estimate of IMR from the proportion of deceased among children born to women of five years age group and the mean age at child bearing.

$Z_i \forall i = 1, \ldots, 6$ stand for the IMR (per person) experienced by women in the age groups 15-19, 40-44.

Now, the LGP is formulated as follows

Minimize $d_1 + d_2 + d_3 + d_4$, such that

\[
\begin{align*}
\beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + d_1 &= \xi_1 \tag{3.2.2.1} \\
\beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + d_2 &= \xi_2 \tag{3.2.2.2} \\
\delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + d_3 &= \xi_3 \tag{3.2.2.3}
\end{align*}
\]
In equations (3.2.2.1) to (3.2.2.4), \( \xi_1 \) and \( \xi_2 \) are two limits between which the overall IMR has to lie. These can be taken as goals for this LGP. \( \xi_1 \) and \( \xi_2 \) are predetermined from the past records. By taking \( \pm 3 \sigma \) limits of the mean (\( \mu \)) from IMR of the past five years data. Equations (3.2.2.5) and (3.2.2.6) show the relationship of the proportion of infant deaths to the married women of the age groups 15-19, 20-24 and 25-29. Equation (3.2.2.7) shows the relationship between the estimated and observed IMR basing on the proportion of deceased among children born to women of five-year age group. It has been observed that the accuracy of the estimate of IMR also depends on onset of child bearing and declining mortality of children by age of mother. IMR happens to decline more when child bearing starts early and
the age of mother is low. Further it is likely that the decline in mortality of children affects the IM estimate more than the decline in fertility. In addition, the quality of data also affects the estimate of infant and child mortality. In fact, the estimate based on data from 15-19 age group seems to be unreliable. Generally, mortality rate of infants for second, third and fifth age groups are taken as reliable estimates of infant mortality for the respective age group and the said estimate for first age group is extrapolated for these values. Using the children ever born and children surviving data ideal value of IMR is found through mean age of child bearing and a relation between observed IMR and Ideal IMR is noted. The constraint (3.2.2.8) gives the pattern for IMR in each age group of the women. This can be taken from the past data. The constraints (3.2.2.9) to (3.2.2.11) specify the limits $p_i \forall i = 1, \ldots, 3$ between which specific $Z_i$ has to lie. which express the proportion of children dying to children born. A certain flexibility based on past experience is incorporated in fixing the range of IMR. Constraints (3.2.2.12) to (3.2.2.14) specify the pattern to be satisfied by IMR which are expressed as functions of the first differences. The model is applied to fertility data of 1981 census study for the state of Orissa.

The programme will run with the following input variables from the data of Orissa, which can be solved in any standard computer package.
\[ \beta_1 = 0.1033; \beta_2 = 0.1867; \beta_3 = 0.2525; \beta_4 = 0.2025; \beta_6 = 0.0686; \]
\[ \delta_1 = 0.0644; \delta_2 = 0.1256; \delta_3 = 0.1912; \delta_4 = 0.1847; \delta_5 = 0.1770; \]
\[ \delta_6 = 0.1592 \]
\[ \xi_1 = 0.123; \xi_2 = 0.157 \]
\[ \gamma_1 = 0.1661; \gamma_2 = 0.2247; \gamma_3 = 0.1831 \]
\[ k_1 = 0.1374; k_2 = 0.1215; k_3 = 0.1138; k_4 = 0.1123; k_5 = 0.1150; k_6 = 0.1201 \]
\[ \rho_1 = 0.1454; \rho_2 = 0.1526; \rho_3 = 0.163 \]
\[ \phi_1 = 0.039; \phi_2 = 0.01; \phi_3 = 0.005 \]

3.2.3 Conclusion

The programme is designed to estimate IMR of different age groups of women and total IMR at micro-level of any state by operating through the standard computer package. The objective of the study is not to show its solution, but lies in identifying the correct rate of infant mortality by using a multi objective programming from a set of indirect data by imposing several restrictions on the estimated IMR simultaneously so that, the mortality environment of the infants of a state like Orissa, where the quality of direct data is very poor, is perfectly represented.