Chapter 4

Data and Methodology

4.1 Data Source

Primarily, two data sources have been used to examine the issues in depth. They are the data from the Medical Certification of Causes of Death Scheme from the Office of the Registrar General & Census Commissioner, India, Ministry of Home Affairs, New Delhi for the years 1989 to 2008 and the data from the Study on Causes of Death by Verbal Autopsy in India, Indian Council of Medical Research, New Delhi (ICMR, 2009).

In the absence of other credible data, MCCD data for the years 1989 to 2008 have been used in the study for fitting age and sex wise trend lines of the major causes of death groups. For estimating the potential gain in life expectancy, MCCD data for the year 2003 have been used because at the time of conceptualization of the research study this was the latest MCCD data under RGI domain (RGI, 2009c).

4.1.1 Medical Certification of Causes of Death

Under the Registration of Births & Deaths Act, 1969, the scheme of Medical Certification of Causes of Death (MCCD) – an integral part of the Vital statistics System, aims at providing a reliable database for generating cause-specific mortality statistics on a regular basis. The Office of the Registrar General, India (ORGI) obtains data on cause of death from the Chief Registrar of Births and Deaths of different States and Union Territories.

The MCCD under Civil Registration System has been implemented in the States/UTs in a phased manner to provide data on cause of death. However, it has so far been implemented in only certain hospitals, generally in urban areas which are selected by the Chief Registrar of Births & Deaths. Thus, the scheme covers mostly those deaths, which occur in medical institutions located in urban areas. The coverage under the scheme in terms of percentage level of medical certification as well as the type of hospitals covered has not been uniform across the States/UTs. Some of the States have notified only teaching and specialized hospitals under it, whereas in
others, only district hospitals and Primary Health Centers (PHCs) have been brought under its ambit.

RGI presents MCCD data as per the National List based on 10th revision of International Classification of Diseases to facilitate meaningful comparison and drawing valid conclusions thereon. The underlying cause of death is taken into account while tabulating the cause-specific mortality under the age groups – <1 year, 1-4 years, 5-14 years, 15-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, 65-69 years, 70 years and above, and age not stated.

As of 2012, 32 States/UTs viz., Andhra Pradesh, Arunachal Pradesh, Assam, Andaman & Nicobar Islands, Bihar, Chandigarh, Chhattisgarh, Dadra & Nagar Haveli, Daman & Diu, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Nagaland, Orissa, Punjab, Puducherry, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh and West Bengal, have issued notification for the introduction of MCCD scheme (RGI, 2012b).

The scheme of MCCD has been functioning at different levels of efficiency in various States/Union Territories. During 2008, 26 States/Union Territories reported the data on MCCD in the prescribed format. The proportion of the registered deaths which are medically certified for the cause of death varies widely across States and Union Territories. Goa is the only state in the country where all the registered deaths are medically certified for the cause of death followed by 76.7% in Manipur and 63.2% in Puducherry. In Nagaland and West Bengal, less than 5% of the registered deaths are medically certified for the cause of death. Amongst major States, the highest level of medical certification of cause of death has been observed in Maharashtra (34.6%), which stands at the eighth rank (Table 4.1) (RGI, 2012b).
Table 4.1: Ranking of States/Union Territories in the Medical Certification of Causes of Death during 2008

<table>
<thead>
<tr>
<th>S. No.</th>
<th>State/Union Territory</th>
<th>Total Registered Deaths</th>
<th>Total Medically Certified Deaths</th>
<th>Percentage of Medically Certified Deaths to Total Registered Deaths</th>
<th>Rank of State/Union Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Andhra Pradesh</td>
<td>412561</td>
<td>61469</td>
<td>14.9</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>A &amp; N Islands</td>
<td>1824</td>
<td>985</td>
<td>54.0</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Assam</td>
<td>80211</td>
<td>21917</td>
<td>27.3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Bihar</td>
<td>168133</td>
<td>12602</td>
<td>7.5</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Chhattisgarh</td>
<td>107017</td>
<td>8266</td>
<td>7.7</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>Delhi</td>
<td>107600</td>
<td>54960</td>
<td>51.1</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Goa</td>
<td>11891</td>
<td>11891</td>
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<td>1</td>
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<tr>
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<td>14</td>
</tr>
<tr>
<td>9</td>
<td>Haryana</td>
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<td>23478</td>
<td>16.3</td>
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<tr>
<td>10</td>
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<td>Karnataka</td>
<td>372062</td>
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<td>30.3</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Kerala</td>
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<td>21107</td>
<td>9.5</td>
<td>22</td>
</tr>
<tr>
<td>13</td>
<td>Madhya Pradesh</td>
<td>304783</td>
<td>34538</td>
<td>11.3</td>
<td>16</td>
</tr>
<tr>
<td>14</td>
<td>Maharashtra</td>
<td>629770</td>
<td>217642</td>
<td>34.6</td>
<td>8</td>
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<tr>
<td>15</td>
<td>Manipur</td>
<td>3323</td>
<td>2548</td>
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<tr>
<td>16</td>
<td>Meghalaya</td>
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<td>17</td>
<td>Mizoram</td>
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<td>2414</td>
<td>43.2</td>
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<td>18</td>
<td>Nagaland</td>
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<td>214</td>
<td>2.9</td>
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<tr>
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<td>Orissa</td>
<td>272417</td>
<td>30693</td>
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<tr>
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<td>Puducherry</td>
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<td>24</td>
<td>Tamil Nadu</td>
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</tr>
<tr>
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<td>Uttarakhand</td>
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<tr>
<td>26</td>
<td>West Bengal</td>
<td>360977</td>
<td>12818</td>
<td>3.6</td>
<td>25</td>
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</tbody>
</table>

(Source: RGI, 2012b)

The time series data on MCCD for the years 1986 to 2008 reveals a significant long-term growth in absolute numbers of medically certified cases. There has been a consistent but slow increase in the number of States implementing the MCCD scheme. During these years, the share of medically certified deaths in total registered deaths has been as low as hovering around 13–19%. This is a serious cause of concern and entails proper prioritization in effective implementation of the scheme by the States/Union Territories. The growth in medical certification of cause of death during last 23 years is given in the table 4.2 (RGI, 2012b).
Table 4.2: Growth in the percentage of medically certified deaths to total registered deaths in India during 1986-2008

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of States/UTs Reported Data</th>
<th>Total Number of Registered Deaths</th>
<th>No. of Medically Certified Deaths</th>
<th>Percentage of Medically Certified Deaths to Total Registered Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>14</td>
<td>1941899</td>
<td>259370</td>
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<td>1987</td>
<td>15</td>
<td>2089559</td>
<td>336055</td>
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<td>1988</td>
<td>18</td>
<td>2579902</td>
<td>368315</td>
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</tr>
<tr>
<td>1989</td>
<td>16</td>
<td>2389968</td>
<td>336736</td>
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<td>1991</td>
<td>15</td>
<td>2616122</td>
<td>384235</td>
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</tr>
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<td>1992</td>
<td>15</td>
<td>2305398</td>
<td>374839</td>
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<td>1993</td>
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<td>1994</td>
<td>16</td>
<td>2770694</td>
<td>374141</td>
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<tr>
<td>1995</td>
<td>17</td>
<td>2736387</td>
<td>388201</td>
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<td>2994244</td>
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<td>1997</td>
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<td>13.0</td>
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<td>1998</td>
<td>23</td>
<td>3353703</td>
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<td>14.9</td>
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<tr>
<td>1999</td>
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<td>3603741</td>
<td>488619</td>
<td>13.6</td>
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<td>2000</td>
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<td>2001</td>
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<td>4251632</td>
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<td>2008</td>
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<td>4560901</td>
<td>878339</td>
<td>19.3</td>
</tr>
</tbody>
</table>

(Source: RGI, 2012b)

Percentage distribution of medically certified deaths to total registered deaths in selected states for the period from 2006 to 2008 is shown in Table 4.3. Over the years, Maharashtra is showing a downward trend in the percentage of medically certified deaths to the total registered deaths. Tamil Nadu is showing an upward trend. Bihar and Rajasthan are showing fluctuating trends.
Table 4.3: Percentage of medically certified deaths to total registered deaths in selected states during 2006-2008

| S. No. | States     | Total Registered Deaths 2006 | 2007 | 2008 | Total Medically Certified deaths (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bihar</td>
<td>172789</td>
<td>176040</td>
<td>168133</td>
<td>6.6</td>
</tr>
<tr>
<td>2</td>
<td>Maharashtra</td>
<td>568611</td>
<td>603112</td>
<td>629770</td>
<td>36.8</td>
</tr>
<tr>
<td>3</td>
<td>Rajasthan</td>
<td>315308</td>
<td>323587</td>
<td>328953</td>
<td>10.7</td>
</tr>
<tr>
<td>4</td>
<td>Tamil Nadu</td>
<td>443503</td>
<td>433970</td>
<td>429981</td>
<td>22.9</td>
</tr>
</tbody>
</table>

(Source: RGI, 2012b)

4.1.2 Study on Causes of Death by Verbal Autopsy in India

Review of cause of death reporting system in India conducted by Registrar General of India indicated the need of improved and valid data collection system taking care full coverage of death reporting, minimal use of residual categories such as unclassifiable or ill-defined conditions, systematic screening of cause of death reports, and timeliness of publication of reports. Keeping these into consideration, Indian Council of Medical Research (ICMR) initiated a study entitled “Study on causes of death by verbal autopsy in India” with the objectives to assess probable causes of deaths in male and female population in selected states of India and to study socio-economic profile of the households with deaths in the study population. It was felt that this kind of data collection system at a large scale to estimate and analyze the cause of death statistics will improve and strengthen the cause of death reporting system in India (ICMR, 2009).

The study was carried out in five states namely Assam, Bihar, Maharashtra, Rajasthan and Tamil Nadu. Using the 1991 census, Assam state was divided into five geographic regions and in Bihar, Rajasthan and Maharashtra each divided into six sub-geographical regions and Tamil Nadu was divided into four zones. In each state, one district from each region/zone was selected by PPS. In Assam, however, fifth region comprising of Karbi Anglong and Cachar was excluded due to the political unrest prevailing in the district (ICMR, 2009).
The sample was designed to provide estimates for the state as a whole. A stratified multi-stage sampling design was adopted. The stratification was geographic with districts being classified into contiguous regions. In each region, one district was selected with probability proportional to size (PPS). In each district, sampling units were villages in rural domain and census enumeration blocks (CEB) in urban domain. A target of 30 sampling units divided between rural and urban areas by allocating the sampling units proportionally to the population of these two areas. The rural and urban samples within each selected district were drawn independently (ICMR, 2009).

The 1991 Primary Census Abstract was used as a sampling frame. In each selected district in rural areas, all the villages were stratified according to population size of the village. The final level of stratification was for all strata, consisting of an ordering of village by the level of female literacy. From the list of villages arranged in this manner, villages were selected systematically with probability proportional to population size (PPS) of the village (ICMR, 2009).

In each of the selected district, in urban area, all the urban wards were arranged by level of female literacy, and a sample of wards was selected systematically with probability proportional to population size. Next, one Census Enumeration Block (CEB) consisting of approximately 150–200 households, was selected from each selected ward using the simple random sample method (ICMR, 2009).

In the selected village in rural area (or CEB in urban area) from each household for all deaths which occurred during January 1 to December 31, 2003, detailed information on causes of deaths were collected using verbal autopsy methodology. In Maharashtra, there were a high proportion of villages with larger population. Therefore, selected villages with population more than 1000 were divided number of segments more or less size and one segment was selected randomly (ICMR, 2009).

Cause of death assignment was done using validated materials and processes developed by the Registrar General of India’s Sample Registration System (RGI, 2003). Each verbal autopsy was assessed independently by trained medical persons.
where each assigned an underlying cause of death for all cases with immediate and contributory causes also assigned wherever possible. Causes of death were selected from a restricted list derived from the 10th version of the international classification of disease (ICD-10) (WHO, 1993). The causes selected for inclusion in the list comprised the main causes of death, which was considered that the medical persons can reasonably assign on the basis of the information typically collected in a verbal autopsy. Assignment of the causes of death by the medical persons was facilitated by a series of algorithms developed for the Sample Registration System (RGI, 2005a).

The survey was conducted twice a year at six months interval. Fixed reference period of six months (January-June or July-December 2003) was used for conducting the survey wherein one district was covered at a time. The events (deaths) which occurred during the one year reference period (January 2003 to December 2003). The total number of deaths covered by verbal autopsy was 1963 in four districts of Assam, 3479 in six districts of Bihar, 1556 in six districts of Maharashtra, 3157 in six districts of Rajasthan, 3833 in four districts of Tamil Nadu in the year 2003. The different age groups studied were infants (0-11 months), children below 5 years, 5-14 years, 15-24 years, 25-44 years, 45-59 years, and 60 years and above (ICMR, 2009).

In Bihar where 30% of deaths occurred due to infectious and parasitic diseases, over one-third deaths were due to either diseases of respiratory system; or diseases of circulatory system; or symptoms, signs and abnormal clinical and laboratory findings not elsewhere classified. Certain conditions originating in the perinatal period; and injury, poisoning and certain other consequences of external causes were other important causes of death in the state. In Rajasthan, over one-third deaths were due to certain infectious and parasitic diseases. Another one-third deaths were either due to symptoms, signs and abdominal clinical and laboratory findings not elsewhere classified (11%); or due to diseases of respiratory system (11%); or diseases of circulatory system (10%). In Maharashtra, one-quarter of deaths were due to diseases of the circulatory system followed by certain infectious and parasitic diseases (17%); diseases of respiratory system (10%); symptoms, signs and abnormal clinical and laboratory findings not classified elsewhere (9%); external causes of morbidity and mortality (6%); and diseases of the digestive system (5%). In Tamil Nadu, diseases of circulatory system, accounted for 24% of deaths followed by certain
infectious and parasitic diseases (16%); and injury, poisoning and certain other consequences of external causes (14%). The other important causes of death in the state were symptoms, signs and abnormal clinical and laboratory findings not classified elsewhere; and neoplasm (9% each) (ICMR, 2009).

4.2 Methodology
After going through the reports of Medical Certification of Causes of Death for the period from 1989 to 2008, it was observed that there were a large number of deaths under the head ‘NS’ (Age Not Stated). After reviewing literature and doing a series of exercises, it was thought appropriate to distribute these deaths in all stated age groups in proportion to total deaths at those age groups. This was done for all the years for all causes of deaths by age and sex. Proportion of each cause of death to total deaths by age and sex was also calculated.

To study the cause of death pattern in India and selected States trend lines have been fitted for cause of death for the period from 1989 to 2008 by age and sex. In an earlier exercise, when original rates were applied in analysis, it was found that the results were giving fluctuated trends. Therefore, in the next exercise, trend lines were fitted by calculating the proportion of each cause of death to total deaths by age and sex. However, in this exercise also the results were showing upward and downward trends. Therefore, to remove these fluctuations and to have smooth trends, 3 years moving average of proportion of each cause of death to total deaths have been calculated, analyzed and discussed in the next chapter. Data for Bihar is available from 2002 to 2008 and hence the trend lines have been fitted by applying 3 years moving average and discussed in the next chapter.

To study the influence of cause of death on longevity, "abridged life table” and its applications - multiple decrement life table and cause eliminated life tables have been prepared and potential gains in life expectancy by partial and complete elimination of cause of death by age and sex by using MCCD data for the year 2003 have been calculated.

Cause of Death is the disease or injuries that initiated the train of morbid events leading to death, or the circumstances of accident or violence, which produced
the fatal death. Life expectancy is the average number of additional years a person could expect to live if current mortality trends were to continue for the rest of that person’s life. Most commonly cited is life expectancy at birth. Mortality levels are explained as the levels of the death rate which are different and depend on the size of each cause. The rates of all causes are indicated per 1000 population in a given year. Age specific death rate (ASDR) is a death rate calculated from the number of deaths at age x to the population at risk. The ASDR usually are semi-log graphically constructed U-shape mortality pattern which change into J-shape. Cause specific death rate is the number of deaths attributable to a specific cause per 1000 population in a given year. Crude birth rate (CBR) is the number of live births per 1000 population in a given year. Crude death rate (CDR) is the number of deaths per 1000 population in a given year. Infant mortality rate (IMR) is the number of deaths of infants under age 1 per 1000 live births in a given year. Sex ratio represents the number of females per 1000 males in a population.

4.2.1 Verbal Autopsy Process

Verbal autopsy method has been used in various settings with different patterns of disease prevalence (WHO/UNICEF, 1994), and most studies have developed their own questionnaires and criteria to arrive at a diagnosis. This has introduced considerable variation in verbal autopsy based mortality surveillance system, but essentially there are two main processes. Firstly, data collected to obtain the information about the events leading to the death of the individual and secondly, these data used for cause of death assignment (Srivastava et al., 2001). A third highly desirable but non-essential aspect of the verbal autopsy process is a validation study done to objectively evaluate the likely robustness of the cause of death data obtained. Where the verbal autopsy method is being used as part of mortality surveillance system this may best be done by broader validation of the entire system.

A. Data Collection

Interviewers collect information regarding the events prior to death from a relative/caregiver of the deceased. This data, usually recorded on a questionnaire, is assessed by medically trained personnel who arrive at a cause of death based on the information collected. The key issues that affect the quality of the data collected are the format of the questionnaire, the interviewer who collects the data, the respondent
and recall period (Chandramohan et al., 1998).

a. Questionnaire

The questionnaire, usually in two or three sections, seeks to collect information about general characteristics of the deceased such as age, sex, education, occupation, health service utilization, risk factors (such as smoking and alcohol intake), medical tests conducted, medical history, followed by questions on signs and symptoms of the illness preceding the death. Verbal autopsy questionnaires can be divided into three broad categories:

1) Unstructured questionnaire (Open ended/narrative),
2) Structured questionnaire (Closed ended), and
3) Combined questionnaire (Open and closed ended)

b. Interviewers

There are multiple aspects of the interviewer that may have a bearing on the success of the verbal autopsy process, including age, sex, education, ethnicity and language. Probably the most important of these is the level of education and type of questionnaire format used. Ideally, the interviewer’s knowledge about medical terminology and interviewing skills should be reasonably good particularly if an unstructured questionnaire is used. The interviewer who performs the verbal autopsy should preferably be someone who understands the local customs and language, specifically the regional dialect.

c. Respondent

The best respondent is one who can provide the most accurate account of the events that occurred before the death. The choice of the respondent usually depends on his/her proximity to the deceased during the period of illness and at the time of death. Family members who lived with the deceased during their illness usually remember easily recognizable symptoms and signs of illness preceding death and can give an accurate account of the circumstances leading to death. The preference for respondent also varies according to age of the deceased.
d. Recall period

Recall period describes the time lag between the occurrence of the event and time of the interview. The recall period for a verbal autopsy interview is a balance between providing sufficient time for family to get over the worst of the grieving period, but keep the period short enough to minimize the problem of recall error.

B. Cause of Death Assignment

Cause of death assignment is the second main step in the verbal autopsy process utilizing the data collected to assign a specific cause of death. There are two main procedures that are used:

1) Medical assessment (physician review)
2) Diagnostic criteria or guidelines

*Medical assessment:* In this method, a physician reviews the questionnaire and arrives at a cause of death using his/her clinical judgment. This process is similar to making a diagnosis using a medical history except without a physical examination or direct contact with the patient. Cause of death assigners require a good understanding of the verbal autopsy method used and need to be trained in the International Classification of Diseases and Related Health Problems (ICD) in order to assign specific codes to causes of death. Medical assignment of cause of death is usually done by physicians, though non-physician coders have been used to assign causes of death in a few studies.

*Diagnostic criteria:* Diagnostic criteria (Diagnostic algorithms) use features of the symptoms and signs of the disease to move the cause of death assigners through a semi-structured process that leads to a cause of death. Diagnostic criteria may use multiple ‘boolean combinations’ of signs, symptoms, and duration of illness and age of the deceased.
e. Single or multiple causes of death

To date, verbal autopsy studies have variously assigned single or multiple causes of death. The World Health Organization and the International Statistical Classification of Diseases provide clear definitions regarding underlying, contributory and immediate causes of death. Studies using single cause of death reporting focus on the underlying cause of death and have the advantages of simplicity. By allowing multiple causes of death, all conditions may be included with malnutrition listed as contributory, diarrhoea as underlying and dehydration as immediate cause of death. Analysis can be conducted on a single cause if required, typically using the underlying cause of death. Combination categories of multiple diagnoses that occur together have also been suggested, for example, malnutrition and diarrhoea can usefully be grouped together. In some circumstances, knowledge of whether single or multiple causes of death were assigned is essential to the interpretation of a verbal autopsy study and likewise, information about the strategy used to select between underlying, immediate, and contributory causes of death. Over the years, the use of multiple causes of death has become more common and is considered to be a better method of coding verbal autopsies.

C. Validation

The validity of a verbal autopsy method depends on how each of the previously described aspects of data collection and cause of death assignment are incorporated into the process. Since the methods vary so markedly all verbal autopsy studies should ideally have a proportion of deaths validated against a reference diagnosis. The reference diagnosis is usually one made at a post mortem examination or based on a comprehensive medical record.

D. Standardization

Verbal autopsies have been widely used in research projects and for governmental mortality surveillance systems for over five decades across many different countries (Chen et al., 1974; Herrera et al., 1992; Awasthi and Pande, 1998; Fantahun, 1998; Bang et al., 2002; Bartlett et al., 2002; Doctor and Weinreb, 2003). Studies have been done to serve diverse purposes and the methods used have varied substantially. Since the results of such systems are used for functions such as
4.2.2 Life Table

Life table is a tabular display of life expectancy and the probability of dying at each age (or age group) for a given population, according to the age specific death rates prevailing at that time. The life table gives an organized, complete picture of a population’s mortality.

John Graunt derived the very first life table and published his famous paper “Natural and Political Observations Made Upon the Bills of Mortality” in 1662. Although it was too rough, lacking in detail, and inaccurate, it was the beginning of demography studies and thus he was honored with the title "Father of Demography" (Dublin, et al., 1949).

The first life table developed in a logical way was published in 1693 by Halley. It was based on birth and death registration data for the city of Breslau for the years 1687 to 1691. The assumption adopted in the preparation of this table was that the population of Breslau had remained stationary (Halley, 1693).

The first scientifically correct life table based on both population and death data classified by age was prepared by Milne and published in 1815. It was based on the mortality experience in two parishes of Carlisle, England, during the period 1779–1787. A large number of life tables have been published since then. In the early years, most of these pertained to European countries, particularly Scandinavian countries.

In 1925, Lotka constructed the first modern life table. He developed a mathematics model to study fertility. After that the United States official complete life tables were prepared during 1900-1902 in connection with the decennial censuses of population. The United States life tables constructed from death statistics were separated into several life tables for whites, blacks, males and females, etc. Although a life table was first designed to measure mortality, it is employed by a variety of specialists. It is used in studies of longevity, fertility, migration, and population
growth as well as in making projections of population size and characteristic. Also the resulting values are used to measure mortality, survivorship and life expectancy. In other applications, the mortality rates in the life table can be used to study the causes of death by cohort and cause elimination, etc.

4.2.3 Types of Life Tables

The standard life table technique can be applied in a variety of ways. Its application is an advantage in cause of death studies; for example, the multiple decrement life table and cause eliminated life table. The latter is useful under the assumption that causes of death can be completely removed or eliminated. Thus, the people are saved and nobody dies from these causes. To select the study tools and gain advantages from the results it is necessary to understand the life table concept and its evolution by time.

4.2.3.1 Current and Cohort Life Table

Life tables differ according to the reference year of the table, the age detail, and number of factors comprehended by the table. Life tables can be categorized into two types according to the reference year of the table. One is the current or period life table and the other is the cohort or generation life table. The current life table is based upon the mortality experience of a community for a short period of time such as one year, three years of an inter-censal period during which the mortality of a community has not changed substantially. The current life table does not depict the mortality experience of an actual cohort. It assumes a hypothetical cohort, which is experiencing the ASDRs observed during a particular time. A current life table, therefore, may be viewed as a "snapshot" of current mortality. It is an excellent summary description of mortality in a year or a short period. The cohort or generation life table is based on the mortality experience of a birth cohort, i.e., person born during one particular year. This life table would observe the mortality experience of that particular birth cohort from its beginning till the death of all the cohort members. As such, for the construction of cohort life table, data over a fairly long period of years are needed. Hence, cohort life tables are not of much practical value and are not commonly used (Dublin, et al., 1949; Prasartkul and Rakchanyaban, 2002).
4.2.3.2 Complete and Abridged Life Table

According to the length of the age interval there are two types of life tables namely, complete and abridged life tables. In a complete life table information is given for every single year of age from birth until the last applicable age. In abridged life table information is given only for broader age intervals such as x to x+5 years. The use of abridged life tables has expanded because mortality data are usually available and sufficiently accurate in the form of rates for 5-year age groups and not for each individual age. The main reason for providing data in an abridged form is related to the phenomenon of age heaping caused by age mis-statements in data registration. Another reason is the incomplete and unstable documentation of vital statistics and therefore the quality of the data may not permit computation of a complete life table.

4.2.3.3 Abridged Life Table

Several short-cut methods have been designed for preparing abridged life tables. Most of these methods require same type of data. Their main difference is in the way the observed death rates are converted into death probability functions in the life table. Three methods, shortly described here are the Reed-Merrell Method, the Greville Method, and the Chiang method.

4.2.3.3.1 Reed-Merrell Method

Reed and Merrell (1939) proposed a short-cut procedure for constructing an abridged life table. In this method, the mortality rates ($nq_x$) may be obtained from a set of standard conversion tables prepared on the basis of the following empirical relationship between $nq_x$ and $nm_x$:

$$nq_x = 1 - \exp \left( (n,m_x, a,n,m_x^2) \right)$$

where,

- $n$ is the width of the age-interval,
- $nm_x$ is the central death rate and 'a' is a constant.
- Reed and Merrell found that, for all practical purposes the value of the constant 'a' may be taken as 0.008 which produces reasonably good results. The standard tables, based on the empirical relationship, were prepared for converting the value of $5m_x$ and $10m_x$ into $5q_x$ and $10q_x$ values for all ages from $3m_2$ into the...
corresponding value of $3q_2$.

For the younger ages (i) ages under 1, 1-2 and 2-4 or (ii) ages under 1, and 1-4, separate conversion tables were also worked out by them.

After obtaining $nq_x$ column of a life table, the $l_x$ column and $nd_x$ column can be obtained from the following formulae:

$$l_{x+n} = (1-nq_x)l_x$$ and $$nd_x = l_x - l_{x+n}$$

4.2.3.3.2 Chiang Method

Chiang's method is based on the derivation of a relation for $nL_x$ in terms of $nax$, where $nax$ is the fraction of the interval between $x^{th}$ and $(x+n)^{th}$ birthday anniversaries lived on average by those dying within that interval. To calculate $nL_x$ following formula is used:

$$nL_x = nL_{x+n} + nna_x nd_x$$

On the basis of extensive empirical investigations Chiang (1960) found that the sequence of $nax$ values are rather invariant across sub-population. On that basis he has recommended that once these fractions are computed on the basis of detailed data for one population at one point of time, they can be used for the same population at other points of time and for many other populations at many points of time. The formula for computing the probability of dying within $n$ years from the $x^{th}$ birthday anniversary can be expressed as follows.

$$nq_x = \frac{nnm_x}{1 + n(1-na_x)n m_x}$$

Once the basic life table function $nq_x$ has been estimated the remaining functions are calculated in a straightforward manner.

4.2.3.3 Greville Method

This method was suggested by Greville in 1943, which converts the observed central death rates to the mortality rates by the formula:
\[
\frac{n^{Mx}}{1/n + n^{Mx} \left[1/2 + n/12(n^{Mx} - \log e C)\right]}
\]

In this equation, it is assumed that the observed death rate (\(n^{m_x}\)) is exponentially related to age (\(x\)) in accordance with the Gompertz law of mortality. In other words, there is a linear relationship between age (\(x\)) and the natural log of the observed death rate (\(\ln n^{m_x}\)). A convenient approximation for \(C\) may be taken as \(\log e C = 0.09\), though the values of \(\log e C\) mostly vary between 0.080 and 0.104. The central death rate in the life table and the population are assumed to be the same, and the desired value of \(n^{L_x}\) can be calculated by a specific formula. In this case the value for \(q_0\) is assumed to equal the infant mortality rate (IMR) (Greville, 1943).

Other life table functions namely \(l_x, L_x, T_x, e^0_x\) are calculated in usual manner.

One difference among the methods is the transformation from the observed death rate (\(n^{m_x}\)) to the mortality rate (\(n^{q_x}\)). The observed annual death rate is the ratio of the deaths to the population count. The mortality rate relates deaths to the appropriate population exposed to the risk of death at the beginning of the age interval.

After comparing all the methods, Greville's method (Greville, 1943) has been selected for constructing life tables in this study because RGI generated the life tables by using MORTPAK, a United Nations software package for mortality measurements (United Nations, 1998) which is based on this method.

### 4.2.3.4 Multiple Decrement Life Table

Conventional life tables represent the reduction of the life table cohort by mortality alone. Life tables with multiple decrements describe how attrition from more than one factor reduces the life table cohort. A double decrement table is a type of multiple decrement life tables in which there are two forms of exit from the initial cohort, one of which is mortality and the other is some change in social or economic status. One example is a nuptiality (marriage formation) table, which follows a cohort of never-married persons as they are exposed to marriage rates and death rates. Another example of a double decrement table is one that follows a cohort of first
marriages as they are exposed to divorce and mortality. Multiple decrement tables allow for several decrement factors (including death). An example of a multiple decrement table is a cause-of-death life table, which subdivides the conventional life table into component tables for the causes of death. This type of table provides information about the population eventually dying of each cause and their average age at death as well as the probability that a person will eventually die from that cause. The multiple decrement tables conceptually traces a cohort of newborn babies through their entire life under the assumption that they are subject to current observed schedule of age-specific mortality rates from different causes of death. In constructing a multiple decrement table, one first constructs a conventional life table using age-specific probabilities of dying for all causes combined. Then, from the counts of actual deaths by cause, the proportion of deaths due to each cause is computed. Next, sub-division of life table deaths by cause is made on the basis of the actual distribution of deaths by cause at each age.

4.2.3.5 Cause Elimination Life Table

Cause elimination life tables are usually based on the assumption that eliminating one cause of death has no effect on the risk of dying from the remaining causes. The potential gain in life expectancy as measured by cause elimination life tables is constrained by the fact that individuals saved would be immediately subject to the death rates from other causes, usually major causes in later life. This phenomenon is called “competing risks.” Because death from the cause eliminated would often have occurred at the older ages, few additional years would be added if the individual survived and died shortly after from another cause. Cause elimination life tables are usually constructed in association with cause of death tables. They also use information about the actual distribution of deaths by cause at each age.

Such cause elimination life tables describe the hypothetical situation that a cause of decrement has been eliminated. This is the same as assuming that the probability of dying from that cause is zero. Deaths from a cause are assumed to disappear, the disease itself is not assumed to go away.

However, when making inferences with the cause elimination life tables, it should be noted that these life tables are simple mathematical models, based on the
assumption of the independence of diseases. In real life, many diseases are not independent, and death is often the end of a complex process. Taking all relevant disease interactions into account would increase needs for data and complexity of models. Hence, though it is not correct in a strict sense, the use of the cause elimination table provides insights about average impact of the particular disease on the mortality experience of the population. Total elimination of a major cause of death is not bio-medically feasible (Dublin, et al., 1949).

4.2.4 Life Table Construction

The most fundamental step in life table construction is of converting observed age-specific death rates ($a_{mx}$) to the mortality rates, or probability of dying ($a_{qmx}$). Followed by computing each entry in the survivor column $l_x$, which is the number of persons living at the beginning of the indicated age interval $x$, and calculating the number of persons who would die within the indicated age interval $x$ to $x+n$ ($a_{dx}$), the next step is calculating the number of person-years that would have lived within the indicated age interval $x$ to $x+n$ ($a_{Lx}$). The last step is the computation of the total number of person years that would have lived after the beginning of the indicated age interval ($T_x$). The total person years lived in a given interval plus subsequent intervals, when finally divided by the number of persons living at the start of that interval, is the life expectancy ($e_x$). It is the average number of years remaining for a person at a given age interval (Shryock, et al., 1971; Population Reference Bureau, 2000; Prasartkul and Vapattanawong, 2001). Life expectancy is a hypothetical measure under the assumption of constant age-specific death rate ($a_{mx}$). In addition to measuring mortality, the life table is not only useful for projection and studying the mortality trends, but also for deriving the indicator of health condition.

1. The first step is one of the most important aspects of preparation of a life table, namely, the testing of data for possible biases and other errors, adjusting data on births, deaths, and population in order to be fully accurate. The number of people or deaths at unknown ages is distributed to the known age categories in proportion to the total number at those ages in order to create abridged life table, multiple decrement and cause eliminated life table in the next step.
2. Construction of the abridged life table with Greville's method. The life expectancy resulting from the life table will be used to compare the difference between the general population dying of all causes and life expectancy calculated from life table applications in steps 3 and 4.

3. Construction of the multiple decrement life table is done with the death by each selected cause, in order to investigate life expectancy of the people who died by each cause. They present the age structure of death by selected cause, which shows the difference occurring in younger, older or other age groups.

4. Construction of the cause elimination life tables is done with the probability of surviving function, which was derived from the abridged life table in step 2. Each life table gives an expectation of life at each age group. Then the life expectancy between the two types of life table is compared. The difference between the values of the expectation of life at each age group before and after eliminating a specified cause of deaths are the number of years of life gained by elimination.

Net probabilities of death due to the cause \( c_a \) were computed by the following formula (Namboodiri and Suchindran, 1987)

\[
\overline{a}q_{x, a} = \frac{n d_{x, a}}{l_x - \frac{1}{2} n d_{x,(a)}},
\]

where, \( n d_{x,(a)} \) = the number of life table death due to all causes except the particular cause \( c_a \) = \( n d_{x, a} - n d_{x, (a)} \)

where \( a n d_k = \) death due to all causes, \( n d_{k, a} = \) death due to the cause \( c_a \) and \( l_x \) is obtained from the table for all causes combined.

This formula makes use of death from causes other than \( c_a \) as withdrawals. A computational formula to estimate the change in life expectancy at age ‘a’ due to partial elimination of the cause of death (\( c_a \)) is given by (Namboodiri and Suchindran, 1987).
\[
H_a^{(a)} = 1 - \frac{1}{e^\alpha} \sum_{i=a}^{\infty} \frac{(l_{x,a})(a l_x)}{n M_{x,a} + a_n M_x} \left\{ 1 - \exp\left[-\left(n M_{x,a} + a_n M_x\right)\right] \right\}
\]

and the amount of gain in life expectancy \( (e_a^0) \) at age ‘a’ after partial elimination of the cause \( (c_a) \) is obtained by \( \delta H_a (a) e^0_a \).

where,

\[e^0_a = \text{The life expectancy at age ‘a’ under the effect of all causes of death combined. This value is obtained from the ordinary life table.}\]

\[n M_{x,a} = \text{The observed age specific death rate for the particular cause } c_a.\]

\[a_n M_x = \text{The observed age specific death rate for all causes combined.}\]

\[l_{x,a} = \text{The ordinate of the survival function for those alive at age ‘x’ and are subjected only to deaths from the cause } c_a. \text{ These values are based on } n q_{x,a}.\]

\[a l_x = \text{The ordinate of the survival function for those alive at age ‘x’ and are subjected to the deaths from all causes combined. These values are based on } a q_x.\]

\[\delta = \text{Percentage level of elimination of a cause of death viz., 25\%, 50\%, 75\% etc.}\]

In addition to the cause of death information, data related to the projected age and sex distribution of the urban population of the selected States has been taken from RGIs’ Report of the Technical Group on Population Projection constituted by the National Commission on Population (RGI, 2006). Urban Crude Birth Rate, Urban Crude Death Rate, Urban Infant Mortality Rate, Urban Age Specific Death Rate and urban sex ratio have been taken from SRS and used in the analysis (RGI, 2005b).
4.2.5 Life Table Applications

Karn (1933) claimed to have developed a method of calculating death rates for the purpose of measuring the effect of death rates from cancer and some other diseases on the expectation of life as given by the English Life Table. Thereafter, Dublin et al., (1949) calculated the years of life gained by elimination of the specific causes of death with the life table prepared on the basis of the data for the United States in 1939-1941. They also discussed potential years of life gained by simultaneous elimination of several causes of death. Greville (1948) calculated the mortality table by causes of death for the United States. United States (1968) calculated and published the United States life table by causes of death between 1959-61. Consequently, when Reed and Merrel (1939) and Greville (1943) presented short-cut methods for constructing an abridged life table, they also commented that it was possible to divide the abridged life table into several causes of death. Thus, the probability of survival in the population must be increased by elimination. From these concepts, a year of life that would be gained if the causes were completely eliminated would obviously affect the life expectancy. Therefore, the life expectancy must be increased, as well (Dublin, et al., 1949; Vacharangkul, 1975).

A compilation of life tables for a large number of countries for a wider period of time has been published by Keyfitz and Flieger (1968, 1990). These life tables were derived electronically from official data on births, deaths, and population classified by age and sex which were considered to be of satisfactory quality. While the first citation concerned only 29% of the world’s population, the second citation refers to 152 countries. The later volume includes actual trends to 1985 and population projections to 2020.

Sets of model life tables have been published by the United Nations (1982), Coale and Demeny (1966); and Coale, Demeny and Vaughn (1983). These sets of tables correspond to values for life expectancy at birth varying generally by fixed intervals in years. The UN tables cover from 20 years to 73.9 years, mostly in intervals of 2.5 years. The Coale and Demeny tables relate to four different “regions” distinguished by the age pattern of mortality. The tables for females correspond to values for life expectancy at birth ranging from 20 to 80 years in intervals of 2.5
years; and the male tables are presented as companion tables. These tables are useful for estimating life table functions for countries where data are under-reported, incomplete and unavailable (Dublin, et al., 1949; Shryock et al., 1971). The World Health Organization annually publishes life expectancy by sex in the World Health Statistics Annual. The Population Reference Bureau frequently publishes life expectancy data in its World Population Data Sheet. Life tables for 229 countries are available from the U.S. Census Bureau’s website.