# 10th Annual EMAB Conference

**Manuscript Number:** **19_12**
**Type of Submission:** **FP**

## Title Page

**Title of Submission:** The long-term effects of CVDs on economic development: the case of Bangalore

**Authors:**

Anitha K. Chinnaswamy[a], Alexeis Garcia-Perez[a], Ian M. Marshall[a], and Raouf Naguib[b]

*[a]Faculty of Business and Law, Coventry University, UK*
*[b]BIOCORE Research & Consultancy International, UK and The Faculty of Science, Liverpool Hope University*

**Abstract**

The aim of this paper is to demonstrate the economic and health burden of Cardiovascular diseases (CVDs) in the context of Bangalore during the period 2010-2013. A data set containing in excess of 1 million historic records corresponding to all-cause mortality was obtained from the central repository data register. After a data quality assessment, a dataset of n=183,893 was obtained. Spatial analysis was carried out to highlight the hotspots of CVD. Potential Years of Life Lost due to CVD and Present Value of Lifetime Earnings were computed. CVDs were responsible for 25% of the total of potential years of life lost. The potential value of lifetime earnings highlighted a loss in excess of 8 billion INR over the four years. CVD poses a tremendous challenge for socio-economic development, and there is an urgent need for a strategic action to promote CVD prevention and enable a sustainable development for the economy.

**Keywords:**

Cardiovascular diseases, economic health burden, GIS spatial analysis, Bangalore, potential years of life lost, present value of lifetime earnings.

# THE LONG-TERM EFFECTS OF CVDS ON ECONOMIC DEVELOPMENT: THE CASE OF BANGALORE

## Abstract

The aim of this paper is to demonstrate the economic and health burden of Cardiovascular diseases (CVDs) in the context of Bangalore during the period 2010-2013. A data set containing in excess of 1 million historic records corresponding to all-cause mortality was obtained from the central repository data register. After a data quality assessment, a dataset of n=183,893 was obtained. Spatial analysis was carried out to highlight the hotspots of CVD. Potential Years of Life Lost due to CVD and Present Value of Lifetime Earnings were computed. CVDs were responsible for 25% of the total of potential years of life lost. The potential value of lifetime earnings highlighted a loss in excess of 8 billion INR over the four years. CVD poses a tremendous challenge for socio-economic development, and there is an urgent need for a strategic action to promote CVD prevention and enable a sustainable development for the economy.

## Keywords

Cardiovascular diseases, economic health burden, GIS spatial analysis, Bangalore, potential years of life lost, present value of lifetime earnings.

## Introduction

Cardiovascular diseases are the world's leading cause of mortality. According to the World Health Organisation (WHO, 2013), an estimated 17.3 million people per year die of CVDs worldwide. Thus, CVD-related deaths accounts for 3 times more than those related to infectious diseases, including HIV/AIDS, Tuberculosis and Malaria combined (Beaglehole and Bonita, 2008). The World Health Organisation estimate that by 2030 the number of deaths due to CVD will increase to 23.6 million, remaining as the single leading cause of death globally (WHO, 2013). Bloom et al. (2011) state that over half of those who die from chronic non-communicable diseases such as CVD are generally in the prime of their productive years. This loss of lives may therefore have a significant impact not only on society but also on the economies of the nations. This is particularly true for low- and middle-income countries as they bear the burden of over 80% of CVD-related deaths per year worldwide.

Despite the abundance of studies stressing the fact that CVDs have a direct impact on socio-economic development, limited research has been conducted to quantify such a burden to the context of a region, a nation or even a city. This highlights the need for research which informs decision making in addressing the challenges posed by CVDs to society.

*Cardiovascular diseases in the context of India*

India is set to become the world's youngest nation by 2020, when the country is expected to have 64% of its population in the working age group. While the western economies, Japan and even China are aging, this demographic potential presents India with an unprecedented edge due to a significant growth rate (The Hindu, 2013).

There is however a threat to India's economic growth. India has witnessed a significant increase in CVDs over the recent decades (Gupta et al., 2011) and CVD has become the top cause of mortality in the country (Ramaraj and Chellappa, 2008). In 1990, CVDs accounted for 63% of all deaths in India, which contributed to 17% of worldwide mortality. Research conducted in the early 2000s by the World Health Organisation (WHO) estimated that by 2010, 60% of the world's cardiac patients would be Indians (Ghaffar et al., 2004). Furthermore, Gaziano (2006) predicted that in this decade 50% of the Indian population who die from CVD will be below the age of 70.

The human, social and economic consequences of CVDs are felt by the society in large. The effects of CVD are not only a health concern but also affects the social aspects of life. As the disease correlates to a decreased life expectancy, there is a huge impact on the individual as well as their family (HealthTalk, 2014). Individuals are known to be concerned about not being able to see their children or grandchildren grow up, they also go through a range of emotions that include anxiety, loss of confidence, anger, frustration, irritability and short temperedness, and depression.

Healthcare in India is highly privatised, with most of the outpatient or inpatient care sourced through the private sector (NSSO, 2006). The large population lacks any form of health cover with nearly 90% of the population paying for healthcare as out-of-pocket (OOP) expenditures (MOHFW, 2005). This form of OOP expenditures has catastrophic effects on households where an individual is affected by CVD. India is witnessing more and more younger people affected by CVD in the country, with an increasing number of them being the sole bread winners for the family has a devastating social and economic impact on individuals and their households.

In abstract economic terms, India was estimated to have lost US$8.7 billion due to affliction from CVD and diabetes up until the end of the last decade (Ajay and Prabhakaran, 2010), and the WHO estimated that this figure reached US$237 billion in over the 10-year period between 2005 and 2015 (Goenka et al., 2009). Furthermore, the GDP of the country was estimated to have fallen by 1% due to the combined economic impacts of CVD and diabetes (Prabhakaran et al., 2016; Abegunde and Stanciole, 2006). There is scientific evidence that indicates that Indians tend to acquire the disease at least 10 years earlier than their western counterparts (Vamadevan et al., 2011). This will have a significant impact on the economically active population due to disability and premature death as a result of the disease. However, despite the relevance of the subject there has been a limited number studies that highlight the statistics of CVD and its actual economic impact in India. Without an understanding of the economic burden of CVDs, it is difficult for decision makers to determine the approach and allocation of resources for management of CVD prevention and control strategies.

This research has been set to demonstrate the potential impact that CVDs may have on socio-economic development. The study is based on the city of Bangalore due to its economic significance for the country's development. By analysing CVD mortality in Bangalore and its impact on economic growth, this research has highlighted the imperatives of a strategy to raise awareness at all levels, from policy makers to the public, on the relevance and potential approaches to CVD prevention and control. To achieve this aim, a data set containing in excess of 1 million historic records corresponding to all-cause mortality in Bangalore was analysed using a Geographic Information System. Hotspots of CVDs in Bangalore were identified, Potential Years of Life Lost due to CVDs and Present Value of Lifetime Earnings were computed, relating these to geographic locations across the city.

## Methods

*Case study rationale*

Although there is a devastating social and economic burden of CVD in India, there have been limited studies to highlight the economic losses that result from these diseases. Access to quality, reliable data about the disease and its impact on society and economy is one of the key barriers to research in this area. Access to a novel data set from Bangalore paved the way to initiate this research, which carried out an intensive examination of mortality and its relation to CVD, taking the Indian city as a case study. Other factors including the explanatory nature of the research, the fact that the phenomenon was to be studied in its real-life context and the multitude of variables related to CVD and its impact on economy and society, made case study an ideal approach to the conduct of this research (Yin, 2009).

*Case study area*

Bangalore is the capital of the Indian state of Karnataka and is home to several major industries, as well as commercial and educational centres. It is also a leading hub for Information Technology (IT) and biotechnology centres. Bangalore is popularly known as the 'Silicon Valley' of South-East Asia. In addition to the wealth of employment and educational opportunities Bangalore offers, it also enjoys a pleasant climate. Bangalore has hence witnessed a population boom with an increased migration subsequently influencing the infrastructure of the city (Aranya 2003). Bangalore has a population of 8.4 million people making it the third largest city in India. The economic growth and the urban evolution have contributed to cultural shifts in lifestyles and behaviours in the city. Although Bangalore is inundated with issues derived from the incidence of CVDs in its population, not enough research has been done to understand the incidence of the diseases and no known study highlights the CVD mortality statistics and their economic impact. This makes of the context of Bangalore an ideal case scenario for the study of the subject.

*Data collection*

Data was obtained from the administrative body responsible for the civic and infrastructural assets of the Greater Bangalore metropolitan area, (the Bruhat Bengaluru Mahanagara Palike – BBMP hereafter). For the purposes of this research, the central repository centre was visited and authorisation was obtained to collect the inputted records from the system. Given the perceived importance of this research and the potential benefits associated to its findings, the researchers were provided with access to the entire database, including a total of n = 1,090,899 historic records for the years 1930–2013. Each of these records included date of death, address, age, gender and cause of death.

*Pre-analysis of the data collected*

A statistical software package, IBM SPSS20, was used for the analysis of the data collected. The variables to be analysed were geographical zone, age groups, year of death, place of death, gender and the cause of death. The data was coded according to cause of death by using the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM). ICD-10-CM is a system used by physicians and other healthcare providers to classify and code all diagnoses, symptoms and procedures recorded in conjunction with hospital care in the United States. ICD-10-CM codes start from A00-Z99, with CVD mortality codes ranging between I00–I99.

*Data cleansing and reduction*

The data set was subjected to descriptive statistical analysis to determine its quality in terms of the parameters described in Table 1. The initial analysis showed that not all of the original n=1,090,899 records had the cause of death recorded. The absence of cause of death does not assist in the analysis of death rates attributed to specific conditions such as CVD. Hence those records were deemed invalid for the purpose of this research.

A second stage in the process of data reduction consisted of the contextual analysis of the data. Given the potential variations in CVD-related statistics as well as in the socio-economic background of Bangalore over the period covered by the data set (1930–2013), the researchers concluded that not all data was valid for the study. It was decided to focus on the data for the last four years (2010-2013), which consisted of a dataset with n=183,893. For the purpose of data quality assessment, the resulting dataset was finally subjected to data quality assessment using the parameters defined by Turner (2002), summarised in Table 1.

Table 1: *Dimensions of Data Quality (Turner, 2002)*

| Dimension | Description |
|---|---|
| Amount of data | Sufficiency/Insufficiency of information |
| Timeliness | Freshness and up-to-date state of information |
| Objectivity | Whether the information was objectively collected |
| Relevancy | Whether the information is useful/relevant/appropriate/applicable to intended purpose |
| Completeness | The expectation that certain attributes are expected to have assigned values in a dataset |
| Accuracy | The level to which stored data agrees with accepted sources of correct information |
| Access security | Whether the information is protected against unauthorised access |

The accuracy of the dataset resulted in 19.4% of the initial number of records being discarded as the cause-of-death recording was either absent or inaccurate. As the geographic distribution of deaths is vital to determine the trends and patterns of deaths, it is necessary that all records have the address of the deceased accurately recorded. The current Medically Certified Cause of Death (MCCD) recording practice in Bangalore does not prioritise the recording of the address of the diseased. This resulted in a further reduction of the valid dataset.

As a conclusion of this stage of the data reduction process the assessment of the current data quality issues in recording mortality events conducted by Chinnaswamy (2015), determined that the system for Bangalore had a completeness level of 73%.

## Results of the data analysis

This section presents a comprehensive analysis of the CVD deaths in Bangalore. Descriptive statistics highlight overall CVD deaths in the city and CVD deaths by zone. Spatial statistics using a GIS map the CVD deaths highlighting the hotspots of the disease in the city. The rate of death, potential years of life lost due to CVD and the present value of lifetime earnings for CVD are computed in this section.

*Descriptive analysis of CVD mortality*

The statistical analysis of the data revealed that the total Non-Institutional deaths over the years 2010-2013 were 86,818 of which 33,075 deaths were due to CVD and 53,743 deaths were due to all other causes. CVDs over the four years on an average contributed to 38.10% of all deaths. Zones West and East had the highest mortality followed by zones South and Mahadevapura. However, when the percentage of total deaths is considered, CVD deaths in zone East was the highest contributing to 50% of the total deaths.

*Mapping of CVD deaths using Geographic Information Systems*

The place where a person lives can influence and often determine their health and health-related quality of life and well-being. Numerous studies have highlighted the relationship between proximity to polluting sources such as highways and the risk of CVD. To aid in determining levels the rates of CVDs in the city, a Geographical Information System (GIS) was employed. GISs have the capability to identify the geographical and geospatial pattern of disease occurrences. Due to their strong capability to perform spatial analysis and decision making capabilities, GIS is gaining popularity in environmental and demographic research areas. An Environmental Health Information System (ENVHIS) based on GIS was developed which allowed the integration of data available and perform spatial analysis.  Choropleth maps of the population highlighting the zones with the highest population were produced. CVD deaths were then geocoded for every zone was also integrated as a layer in the GIS-based system. Overlay techniques were used to superimpose the layers and visualise any patterns. The zones with the highest CVD levels were mapped. Hotspots were also determined at the zonal level (Figure 1).


Figure 1: *Deaths by zone*

This analysis highlighted that the zones West, East and South have the highest CVD mortality rates across the region (Figure 1). Table 2 represents the analysis of deaths by age groups and gender. Although in absolute numbers the quantity of CVDs are highest for the age group 75+, when CVDs affecting early death i.e. below 70 years of age the total number of deaths is 41,388 contributing to 66% of total CVD deaths. This is an important factor to consider as the younger a person dies, the more socio-economic impact there is on the individual's family and the community at large.

Table 2: *CVD deaths by age groups and gender*

| Row Labels | <20 | 20-24 | 25-29 | 30-34 | 35-39 | 40-44 | 45-49 | 50-54 | 55-59 | 60-64 | 65-69 | 70-74 | 75+ | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | 1976 | 367 | 412 | 348 | 601 | 775 | 1203 | 1356 | 1876 | 2292 | 2842 | 2620 | 7461 | 24129 |
| M | 2573 | 491 | 720 | 946 | 1572 | 2093 | 2914 | 3295 | 4005 | 4352 | 4379 | 4060 | 7388 | 38788 |
| **Grand Total** | **4549** | **858** | **1132** | **1294** | **2173** | **2868** | **4117** | **4651** | **5881** | **6644** | **7221** | **6680** | **14849** | **62917** |

However, rather than counting every death as equal, a measure potential years of life lost (PYLL) measurement can provide an appropriate measure of socio-economic impact by recognising that death at younger ages has higher impact than deaths at older ages which is discussed in the following section.

Disability Adjusted Life Years (DALY) measures the losses from disability or death with diseases accounting for more DALY having a higher public health impact (Murray and Lopez 2006). Health measures are then taken to reduce the number of DALY. The DALY has become a key measure employed by the WHO and countries generally perform DALY calculations to assess and monitor their population's health and to set priorities within their health sector.

*DALY formula*

DALY are the sum of years of life lived with disability (YLD) and Years of potential life lost (YPLL), per disease category or outcome, and per age and gender:

$$\text{DALY} = \text{YLD} + \text{YPLL}$$

The YLDs are the morbidity component of the DALYs, and are proportional to the number of incident cases and the severity of the disease:

$$\text{YLD} = \text{Number of Cases} * \text{Disease Duration} * \text{Disability Weight}$$

The YPLLs are the mortality component of the DALYs, and are proportional to the number of deaths and the average age of death. As the comprehensive morbidity data was not available for Bangalore, only the YPLL was calculated.

Years of potential life lost (YPLL), also sometimes referred to as potential years of life lost (PYLL) is defined as an estimate of the average years a person would have lived if he or she had not died prematurely (Gardner and Sanborn, 1990). Hence it can be described as a measure of premature mortality. PYLL gives more weight only to deaths that occur among younger people.

*Calculation*

The years of potential life lost is calculated by setting an upper reference age, this reference age normally corresponds to the life expectancy of the study population. The reference age in developed countries is usually set at 75, but this is lower in developing countries. PYLL is expressed with respect to the reference age [75]. For the purposes of this analysis, an upper reference age was first set to calculate the potential years of life lost. The upper reference age refers to the life expectancy of the Indian population, which has been determined to be 66.21 years (Chauhan and Aeri, 2013). In order to calculate an individual PYLL, the difference between the person's age at death and the reference age is calculated. If the person's age at death is higher than the reference age, it is set at 0. There is no negative PYLL, for example:

1. Reference age = 66; Age at death = 60; PYLL[66] = 66 - 60 = 6
2. Reference age = 66; Age at death = 6 months; PYLL[66] = 66 - 0.5 = 65.5
3. Reference age = 66; Age at death = 70; PYLL[66] = 0

$$PYLL\ (66)(t) = \sum_{i=0}^{66} [D_A(66 - \mathrm{A})]$$

- PYLL (66) is the total PYLL as a result of CVD, at time period t
- $D_A$ - the number of CVD per age group
- A - the age at death by CVD per age group
- $i$ - the number of age groups for $A$ from 0 to 66

To calculate the PYLL for the population over a certain period, the individual PYLLs are summed for all individuals in that population who died in that year. Potential Years of Life Lost (PYLL) provides a way of weighting deaths occurring at younger ages that is preventable. This was undertaken as a cause-specific mortality for Bangalore and it was determined that CVD accounts for 25% of all PYLL in Bangalore during 2010-2013.

Because PYLL gives more weight to deaths among younger individuals, it is the favoured metric among those who wish to draw attention to those causes of death that are more common in younger people. Table 3 provides the PYLLs due to CVD according to age, gender and zone for Bangalore. It can be seen from the table that the middle age groups 35-39, 40-44, 45-49 have the highest PYLLs. For both the genders, the most affected age group is 45-49 after which the PYLL has a decline. However, CVDs have a prominent effect on males with over twice as many PYLL lives lost in males compared to women of the same age group.

Table 3*: PYLLs according to age groups, gender and zone*

| | <20 | 20-24 | 25-29 | 30-34 | 35-39 | 40-44 | 45-49 | 50-54 | 55-59 | 60-64 |
|---|---|---|---|---|---|---|---|---|---|---|
| **F** | **29365** | **15764** | **15738** | **11623** | **17006** | **18187** | **22242** | **18191** | **15855** | **8109** |
| Bommanahalli | 915 | 344 | 566 | 300 | 482 | 392 | 680 | 538 | 493 | 247 |
| Byatarayanpura | 616 | 87 | 272 | 197 | 284 | 570 | 777 | 420 | 587 | 318 |
| Dasarahalli | 392 | 476 | 423 | 196 | 793 | 568 | 677 | 420 | 365 | 218 |
| East | 5647 | 2707 | 2340 | 2214 | 3370 | 3695 | 4992 | 4272 | 4036 | 2013 |
| Mahadevapura | 1713 | 1493 | 1529 | 1232 | 1319 | 1345 | 1818 | 1194 | 1069 | 555 |
| RR Nagar | 805 | 797 | 536 | 363 | 512 | 859 | 849 | 703 | 491 | 245 |
| South | 14278 | 6286 | 6622 | 4720 | 6733 | 6456 | 7435 | 6285 | 5315 | 2729 |
| West | 4999 | 3574 | 3450 | 2401 | 3513 | 4302 | 5014 | 4359 | 3499 | 1784 |
| **M** | **38748** | **21079** | **27422** | **31471** | **44464** | **49124** | **53569** | **43974** | **33290** | **14762** |
| Bommanahalli | 1361 | 684 | 1020 | 1033 | 1191 | 1666 | 1908 | 1392 | 1159 | 498 |
| Byatarayanpura | 248 | 344 | 707 | 1067 | 1668 | 2042 | 1802 | 1485 | 1247 | 519 |
| Dasarahalli | 221 | 811 | 797 | 960 | 1858 | 1616 | 1991 | 1512 | 1137 | 428 |
| East | 7835 | 3551 | 4705 | 6565 | 8382 | 10236 | 12169 | 10054 | 8085 | 3572 |
| Mahadevapura | 3026 | 1528 | 2216 | 2343 | 4134 | 3790 | 3847 | 3311 | 2564 | 1086 |
| RR Nagar | 1250 | 863 | 1018 | 1169 | 2088 | 1758 | 2104 | 1527 | 1319 | 576 |
| South | 17451 | 8466 | 10258 | 11159 | 14479 | 15608 | 17127 | 13863 | 10152 | 4697 |
| West | 7356 | 4832 | 6701 | 7175 | 10664 | 12408 | 12621 | 10830 | 7627 | 3386 |
| **Grand Total** | **68113** | **36843** | **43160** | **43094** | **61470** | **67311** | **75811** | **62165** | **49145** | **22871** |

India is the second most populous country in the world and is projected to be the world's most populous country by 2022. More than 50% of its population is below the age of 25, and more than 65% is below the age of 35. By 2020, the average age of an Indian will be 29 years and the country will thus become the world's youngest country with 64% of its population in the working age group. This demographic potential offers an unprecedented edge and economists believe it could add a significant 2% to the GDP growth rate. While the country's young demographic base is beneficial for India's growth, the threat of CVD to the population is a major challenge. With CVD contributing to over 25% of all PYLLs, there is an urgent need to address the prevention of CVD to all age groups, but in particular the younger population as valuable lives are lost to the disease.

*Present value of lifetime earnings – Loss*

This section describes the estimation of the present value of lifetime earnings (PVLE) for CVD for 2010-2013. PVLE is a simple quantitative measure used to quantify the expected value of lost earnings as contributed to the society by an individual if he or she was able to live out a full lifespan (National Center for Injury Prevention and Control, 2003). The potential economic losses to society are estimated by computing the PVLE for different age and gender groups. The average lifetime earnings for each 5-year age group by gender was obtained from the estimation as provided by Menzin et al. (2012). The estimation is based on the assumption that that all working-age individuals (>20 years) would continue to be employed. Table 4 shows the estimation of PVLE earnings by age and gender. The average lifetime earnings are multiplied by the number of premature deaths for each age group and for every gender group to calculate the expected value of lost earnings in each group. All the monetary values are expressed in Indian Rupees (INR).

Table 4: *PVLE according to age groups and gender*

| Age Range | Male | Female | Grand Total | PVLE_M | PVLE_F | Loss_M | Loss_F | PVLE_Total |
|---|---|---|---|---|---|---|---|---|
| 20-24 | 491 | 367 | 858 | 462,821 | 189,944 | 227245111 | 69709448 | |
| 25-29 | 720 | 412 | 1132 | 480,238 | 210,247 | 345771360 | 86621764 | |
| 30-34 | 946 | 348 | 1294 | 475,296 | 218,157 | 449630016 | 75918636 | |
| 35-39 | 1572 | 601 | 2173 | 462,776 | 212,727 | 727483872 | 127848927 | |
| 40-44 | 2093 | 775 | 2868 | 441,539 | 192,864 | 924141127 | 149469600 | |
| 45-49 | 2914 | 1203 | 4117 | 408,132 | 162,927 | 1189296648 | 196001181 | |
| 50-54 | 3295 | 1356 | 4651 | 354,499 | 119,883 | 1168074205 | 162561348 | |
| 55-59 | 4005 | 1876 | 5881 | 277,836 | 65,703 | 1112733180 | 123258828 | |
| 60-64 | 4352 | 2292 | 6644 | 181,310 | 16,512 | 789061120 | 37845504 | |
| 65-69 | 4379 | 2842 | 7221 | 96,659 | 6,699 | 423269761 | 19038558 | |
| 70-74 | 4060 | 2620 | 6680 | 54,819 | 3,799 | 222565140 | 9953380 | |
| 75+ | 7388 | 7461 | 14849 | 16,056 | 1,113 | 118621728 | 8304093 | |
| | **38788** | **24129** | **62917** | | | **7,697,893,268** | **1,066,531,267** | **8,764,424,535** |

This allows to conclude that the PVLE lost due to CVDs in Bangalore during 2010-2013 was INR 8,764,424,535. As presented in Table 7, it can be noted that the value of lifetime earnings varies for different ages and for genders. For men, the highest peak is at the age groups 25-29 while for women the highest age group is 30-34. It then begins to decrease at a fast rate in the middle age groups. It can be inferred that men have higher lifetime earnings in comparison with women, reflecting their potential for higher market earnings. For males, the highest potential earning groups are 25-29 and their earnings are over 40% higher than for women; by ages 65-69, men’s lifetime earnings are almost 10 times that for women in India.

Lifetime earnings are perceived as a vital component of cost-of-illness studies and is a good approach that values life where productivity is based on an individual's earnings. Pre-mature mortality can hinder the labour force and impact the nation's economic resources considerably. The PVLE measure can highlight the growing economic concern due to early deaths due to a disease and hence promoting interventions.

*Present value of lifetime earnings – Zonal*

As highlighted above, the zones with the highest CVD mortality were East, South and West. The distribution of deaths by gender and age groups was categorised and the PVLE computed for the respective zones by gender and age groups (Table 5). The analysis revealed that the zone West had the highest loss of approximately 2.8 billion INR followed closely by Zone South with 2.7 billion INR. Only these three zones contribute to 87% of the total PVLE in Bangalore.

Table 5: *PVLE according to age groups, gender and zone*

| | 20-24 | 25-29 | 30-34 | 35-39 | 40-44 | 45-49 | 50-54 | 55-59 | 60-64 | 65-69 | 70-74 | 75+ | Grand Total | PVLE_Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **East** | **146** | **184** | **264** | **416** | **597** | **938** | **1085** | **1458** | **1677** | **1681** | **1687** | **3766** | **14920** | |
| F | 63 | 61 | 66 | 119 | 158 | 271 | 320 | 486 | 581 | 675 | 726 | 1898 | 5888 | |
| M | 83 | 123 | 198 | 297 | 439 | 667 | 765 | 972 | 1096 | 1006 | 961 | 1868 | 9032 | |
| PVLE_F | 11966472 | 12825067 | 14398362 | 25314513 | 30472512 | 44153217 | 38362560 | 31931658 | 9593472 | 4521825 | 2758074 | 2112474 | 228410206 | |
| PVLE_M | 38414143 | 59069274 | 94108608 | 137444472 | 193835621 | 272224044 | 271191735 | 270056592 | 198715760 | 97238954 | 52681059 | 29992608 | 1714972870 | **1,943,383,076** |
| **South** | **342** | **443** | **476** | **748** | **938** | **1325** | **1492** | **1827** | **2087** | **2316** | **1993** | **4264** | **19928** | |
| F | 146 | 174 | 141 | 238 | 274 | 400 | 463 | 619 | 747 | 930 | 803 | 2157 | 7822 | |
| M | 196 | 269 | 335 | 510 | 664 | 925 | 1029 | 1208 | 1340 | 1386 | 1190 | 2107 | 12106 | |
| PVLE_F | 138659120 | 30696062 | 37959318 | 29994507 | 45901632 | 44641998 | 47953200 | 30420489 | 10220928 | 5004153 | 3533070 | 893739 | 425878216 | |
| PVLE_M | 438291487 | 94126648 | 127854624 | 155029960 | 225184890 | 270999648 | 327911575 | 285893244 | 219022480 | 129523060 | 75979134 | 19106640 | 2368923390 | **2,794,801,606** |
| **West** | **196** | **266** | **287** | **501** | **708** | **957** | **1134** | **1335** | **1501** | **1707** | **1663** | **3993** | **15304** | |
| F | 83 | 90 | 72 | 124 | 183 | 270 | 326 | 412 | 505 | 693 | 652 | 2060 | 5922 | |
| M | 113 | 176 | 215 | 377 | 525 | 687 | 808 | 923 | 996 | 1014 | 1011 | 1933 | 9382 | |
| PVLE_F | 15765352 | 18922230 | 15707304 | 26378148 | 35294112 | 43990290 | 39081858 | 27069636 | 8338560 | 4642407 | 2476948 | 2292780 | 239959625 | |
| PVLE_M | 90712916 | 127743308 | 136409952 | 231850776 | 312609612 | 390582324 | 402001866 | 370911060 | 272146310 | 164996913 | 91163997 | 64111608 | 2655240642 | **2,895,200,267** |
| **Grand Total** | **684** | **893** | **1027** | **1665** | **2243** | **3220** | **3711** | **4620** | **5265** | **5704** | **5343** | **12023** | **50152** | **7,633,384,949** |

Bangalore is one of the fastest growing economic hubs in India and has an estimated economic growth of 10.3%. With the highest IT-related exports in the country, Bangalore's 523 billion (US$7.8 billion) economy makes it an important economy for India as a whole. Forbes (ICFN, 2013) has described Bangalore as one of "The Next Decade's Fastest-Growing Cities". The city is also home to over 10K-dollar millionaires and over 60,000 super-rich people. However, with the loss of life due to CVD and its associated economic costs, prevention of CVD should be of high priority for the city. The middle age adults have a prime contribution to Bangalore's economy and the loss of early CVD deaths will have a significant socio-economic burden.

## Discussion

A key strength of this study consists of having used data collected by BBMP and the application of an established methodology to estimate the value of productivity losses for the Indian city of Bangalore. The analysis of deaths by zone, gender and age groups has also highlighted the patterns of CVD deaths across the city. However, the analysis was limited by a number of issues related to the nature of the data available for the research. Some of these are highlighted in this section. Although estimates of PVLE have been provided, there is uncertainty over the correct valuation of the average lifetime earnings. While we have used the best approach to valuation based on the available data, the application of a different method might result in a different estimation. Additionally, age-adjusted rates of death could not be determined due to data non-availability, as the population census data does not include the breakdown of age groups.

Finally, using the data available this study could only provide economic estimates related to lifetime earnings for CVD mortality. We are unable to calculate DALYs or loss to households or caring activities because of the unavailability of comprehensive morbidity data. Bangalore has a disintegrated system for morbidity data collection which does not facilitate the estimation of other factors that would help project the economic consequences of CVD prevalence.

## Conclusions

To the best of our knowledge, this study is the first of its kind to provide estimates of CVD statistics and economic implications for a city, based on a country where CVD has been recognised as a major healthcare burden. These findings are applicable to many other cities and countries, which have a similar socio-economic profile to Bangalore. The impact of CVD can be measured as economical, societal or individual. The economic impact measures how the interventions and the subsequent results had an impact on the economy. Ill health adversely affects the development of human capital, which is crucial for a developing economy. The societal impact focuses on the society as a whole. Many of the risk factors that contribute to CVD are further compounded by underlying socio-economic factors as well as environment factors. The right investments will lead not only to better health, but also to longer and more productive lives. This will impact the individual, the individual's family, society and community at large.

CVD in Bangalore is established as not only as a health threat but also a major risk to the economy and development of the city. The analysis in this paper has highlighted that CVDs contribute to approximately 38% of the total deaths in the city, with more men being affected by the disease than women. The study also explored the extant of the PYLL and PVLE losses to Bangalore for the years 2010-2013, estimated in excess of 8 billion INR (more than $120M). It is any government's priority to provide public health programmes and a CVD management program to face the challenges of CVD health issues. The WHO (2011) states that over 50% of the CVDs can be prevented with early interventions. Quality treatment, early diagnosis, good quality medical and nursing care, specialist services - such as surgery and rehabilitation for those with CVD or who are at risk - will facilitate patient recovery and/or wellbeing. The government as a major priority must focus on prevention, diagnosis and treatment.

Evidence has indicated that with timely effective treatment and adequate intervention and prevention measures, the suffering due to CVD can be reduced and prevented. CVD policies are to be based on the best available evidence-based approaches that result from well-conducted, systematic reviews of the relevant evidence. Policies must evolve to incorporate the conclusions of important new research as it becomes available. The spatial analysis conducted allowed for different zones of the city to be identified as the hotspots of CVD, which is also contributing to the highest PVLE. This enables governments to introduce interventions in the zones at most risk first, and this can be achieved through monitoring policies, comprehensive advice services, identification of populations at risk, increasing awareness among public health officials, doctors, health workers on the possible links of air pollution and CVD, and support the raise of public awareness about the health impacts of air pollution.

This research also supports decision makers in designing population-wide interventions such as those raising awareness of factors related to CVD, such as smoking, healthy eating or a healthy lifestyle. Knowledge of dietary factors, for example, can lead to transformational influence on diet and other lifestyle behaviours that can have a direct impact on these diseases in the society. For interventions to take effect it is important to make the interventions people-centric. Thus, the following measure should be promoted:

Bangalore will benefit from evidence-based programs that address the risk factors for CVD. A multi-stake holder approach must be implemented to advocate effective prevention policies to improve population health and tackle inequalities linked to CVD. Additionally, the city would benefit for a revised approach to data collection which would enable future research to provide more accurate advice by including, for example, a breakdown of age groups in the mortality data. Further research could seek to conduct a similar research in other countries with different socio-economic backgrounds, looking for relevant data sets which could allow for more detailed analyses, e.g. by determining age-adjusted rates of death, or estimating losses to households due to CVD.


## Acknowledgements

The authors wish to thank the BBMP for providing the data used for the purposes of this research.


## References


Abegunde, D. and Stanciole, A. (2006) An Estimation of the Economic Impact of Chronic Noncommunicable Diseases in Selected Countries: World Health Organization, Department of Chronic Diseases and Health Promotion (CHP)

Ajay, V. S. and Prabhakaran, D. (2010) 'Coronary Heart Disease in Indians: Implications of the INTERHEART Study'. *Indian Journal of Medical Research* 132 (5), 561-566

Aranya R. (2003) Globalisation and Urban Restructuring of Bangalore, India: Growth of the IT Industry, its spatial dynamics and local planning responses. 39th ISOCARP Congress; India

Beaglehole, R. and Bonita, R. (2008) 'Global Public Health: A Scorecard'. *Lancet* 372, 1988-1996

Bloom, D.E., Cafiero, E.T., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L.R., Fathima, S., Feigl, A.B., Gaziano, T., Mowafi, M., Pandya, A., Prettner, K., Rosenberg, L., Seligman, B., Stein, A.Z., and Weinstein, C. (2011). The Global Economic Burden of Noncommunicable Diseases. Geneva: World Economic Forum.

Chauhan, S. and Aeri, B., T. (2013) 'Prevalence of Cardiovascular Disease in India and it is Economic Impact- A Review'. *International Journal of Scientific and Research Publications* 3 (10)

Chinnaswamy, A.K., Balisane, H., Nguyen, Q.T., Naguib, R.N.G., Trodd, N., Marshall, I.M., Yaacob, N., Santos, G.N., Vallar, E.A., Galvez, M.C., Shaker, M.H., Wickramasinghe, N., and Ton, T.N. (2015) Data Quality Issues in the GIS Modelling of Air Pollution and Cardiovascular Mortality in Bangalore. International Journal of Information Quality 4(1):64-81

Gardner,J., W., and Sanborn,J., S. (1990) 'Years of Potential Life Lost (YPLL)--what does it Measure?'. *Epidemiology* 1 (4), 322-329

Gaziano, T., Reddy, K., S., and Paccaud, F., et al. (2006) *Cardiovascular Disease. in: Jamison DT, Breman JG, Measham AR, Et Al, Eds. Disease Control Priorities in developing world.* . Oxford: Oxford University Press

Ghaffar, A., Reddy, K. S., and Singhi, M. (2004) ' Burden of Non-Communicable Diseases in South Asia.' *Bmj* 328, 807-810

Global Status Report (2014) Global status report on noncommunicable diseases WHO, 2014.

Goenka, S., Prabhakaran, D., Ajay, V. S., and Reddy, K., S. (2009) 'Preventing Cardiovascular Disease in India - Translating Evidence to Action.' Current Science 97 (3), 367-377

Gupta, R., Guptha, S., Joshi, R., and Xavier, D. (2011) 'Translating Evidence into Policy for Cardiovascular Disease Control in India'. *BioMed Central* 9 (8)

HealthTalk (2014) 'Coping emotions after heart attack' [online] available from <http://www.healthtalk.org/peoples-experiences/heart-disease/heart-attack/coping-emotions-after-heart-attack#ixzz4kvagTFKT> [Dec 14 2014]

ICFN (2013) Bangalore 'The Fastest Growing City' in India. [online] available from <http://www.icfn.in/blog/bangalore-the-fastest-growing-city-in-india/> [Jan 04 2015]

Menzin, J., Marton, J. P., Menzin, J. A., Willke, R. J., Woodward, R. M., and Federico, V. (2012) 'Lost Productivity due to Premature Mortality in Developed and Emerging Countries: An Application to Smoking Cessation'. *BMC Medical Research Methodology* 12 (1), 87

MOHFW (2005) National Health Accounts India. New Delhi: National Health Accounts Cell, Ministry of Health and Family Welfare, Government of India;

Murray,C.,J.,L. and Lopez, A.,D. (1996) *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020*. Geneva, Switzerland: Published by the Harvard School of Public Health on behalf of the World Health Organization and the World Bank

National Center for Injury Prevention and Control. (2003). PVLE [online] available from <http://www.cdc.gov/injury/index.html> [June 11 2012]

NSSO (2006) Morbidity, Health Care and Condition of the Aged. New Delhi: Ministry of Statistics and Program Implementation, Government of India. Contract No.: Report No 507 (60/25.0/1).

Prabhakaran, D., Jeemon, P. and Roy, A. (2016) ‘Cardiovascular Diseases in India’. *Circulation* 133 (16), 1605-1620

Ramaraj, R., and Chellappa, P. (2008) 'Cardiovascular Risk in South Asians'. *Postgrad Medical Journal* 84, 518-523

The Hindu (2013) India is set to become the youngest country by 2020. [online] available from <http://www.thehindu.com/news/national/india-is-set-to-become-the-youngest-country-by-2020/article4624347.ece> [February 3 2015]

Turner, S. (2002) 'Defining and Measuring Traffic Data Quality: White Paper'. *Prepared for Federal Highway Administration: Washington D.C.*

Vamadevan, A., S., Shah, B., R., Califf, R., M., and Prabhakaran, D. (2011) 'Cardiovascular Research in India: A Perspective.'. *American Heart Journal* 161, 431-438

WHO (2005) Preventing chronic diseases: a vital investment. [online] available from <http://www.who.int/chp/chronic_disease_report/contents/en/index.html> [July 11 2012].

WHO (2009) Cardiovascular Diseases. [online] available from <http://www.who.int/cardiovascular_diseases/priorities/en/index.html> [July 11 2012].

WHO (2011) *Cardiovascular Diseases* [online] available from <http://www.wpro.who.int/mediacentre/factsheets/cardiovascular_disease/en/> [May 14 2013]

WHO (2013) Noncommunicable diseases [online] available from <http://www.wpro.who.int/mediacentre/factsheets/fs_20120926e/en/> [Dec 13 2015]

WHO (2014) Global status report on noncommunicable diseases 2014 [online] available from <http://www.who.int/nmh/publications/ncd-status-report-2014/en/> [Dec 13 2015]

Yin, R. K. (2009) ‘*Case study research; design and methods*’, London, Sage Publications.