

Capacity Planning For Diabetes Management -Indian Example

Vinaytosh Mishra, Cherian Samuel, S.K. Sharma
Department of Mechanical Engineering
Indian Institute of Technology-BHU, Varanasi, India
vinaytosh@gmail.com

Abstract— Diabetes is becoming an epidemic in India. This chronic disease needs immediate attention of policy makers to control the causalities resulting from it. The deaths due to diabetes are always under reported because people generally die due to involved complications like cardiovascular disease, infections and kidney failures. Moreover, the people from lower income families generally die without proper medical care and their death goes unreported. The research work tries to forecast the number of patients and deaths due to diabetes in India by 2025 and the infrastructure required to handle the situation. The methodology used in the research work is System Dynamics Modeling. The paper will contribute in understanding the capacity needs in terms of the number of beds and doctors required in the year 2025, for management of this chronic disease. It will also help the policy makers in capacity planning for diabetes management in India.

Keywords— Diabetes, Capacity Planning, System Dynamics, Forecasting

I. INTRODUCTION

Diabetes is a physiological state in which level of the glucose in blood is higher than the permissible level [1]. People with diabetes have an increased risk of developing a number of serious health problems. Consistently high blood glucose levels can lead to serious diseases affecting the heart and blood vessels, eyes, kidneys, nerves and teeth. In addition, people with diabetes also have a higher risk of developing infections [2].

The cost of diabetes treatment increases with the complications. The patients with foot complications or with the presence of two diabetic complications tend to stay long for every inpatient admission [3]. Comorbid illnesses can sap the financial resources of people with diabetes by increasing their out-of-pocket costs for medical care. Diabetic patients face higher out-of-pocket medication costs than people with almost any other chronic condition [4,5], and some under use preventive services as a result of cost pressures [6, 7]. The lower income people generally die without proper medical care and their death generally goes unreported.

According to a projection based on 2001 Census, Indian population is expected to become 1392870 thousand by year 2025[8]. WHO estimated diabetes as one of the major, non-communicable causes of death in 2000 for India [16]. Over 30 million have now been diagnosed with diabetes in India and actual number is much higher than this. The organizations like International Diabetes Federation (IDF) reported this prevalence of diabetes as 40.6 million in year 2006. The prevalence of (Impaired Glucose Tolerance) IGT is reported to be around 8.7 % for urban areas and 7.9 % for rural areas though it seems to be over reported. It is thought that 35% of IGT sufferers go on to develop Type- 2 diabetes in future [28]. If out of 1.4 Billion Indian 8% develops IGT and 2.8% eventually develop diabetes. The number of people living with diabetes will reach 39.2 million. Thus, considering the availability of doctors and hospital beds the India is expected to face a healthcare crisis by year 2025.

According to, Ministry of Home Affairs, Government of India, The percentage of medically certified death due to diabetes is reported 1.6% out of the total deaths. This estimation is based on 2011 census [9]. In India the overall mortality rates were nearly three-fold higher in diabetic subjects compared to non-diabetic individuals (18.9 vs. 5.3 per 1000 person-years) [10]. The hazards ratio (HR) for all cause mortality for diabetes was found to be 3.6 compared to non diabetic subjects. Studies show that coronary artery disease as leading cause of death in majority of these studies [11, 12]. However, Bhansali et al [13] and Zargar et al [14] reported that infections were the leading cause of mortality in diabetic subjects. Although studies attribute lower death with diabetes, risk of mortality with other complication is higher in case of person living with diabetes.

Diabetes is the fourth leading cause of death in most developed countries [15]. In a Chennai based study the diabetes is reported as a cause of death in even young population aged between 25-34 year of age. The study uses ‘verbal autopsy’

method, in which trained researchers perform a standard interview with surviving relatives, the results of which are interpreted by experienced physicians. [16].

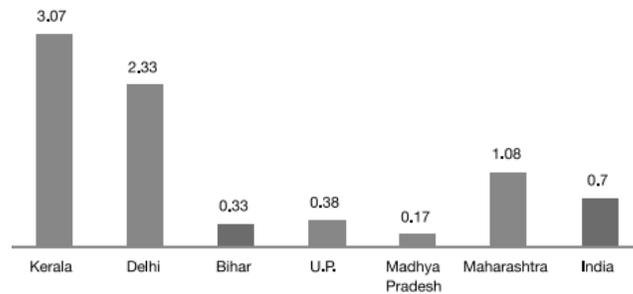
Table 1: Age wise Prevalence of Deaths due to diabetes in Indians

Age Group	25-34	35-44	45-54	55-64	65-69	70-74	75+
Diabetes Death	0.5	1.1	1.5	3.6	4.0	5.4	4.7

India leads the world with largest number of diabetic subjects earning the dubious distinction of being termed the “diabetes capital of the world”. According to the reports (World Diabetes Atlas, 2006) published by the International Diabetes Federation, the number of people with diabetes in India was around 40.9 million in 2006 and is expected to rise to 69.9 Million by 2025 unless urgent preventive steps are taken [29]. Another study published in World Health Organization, reported prevalence of diabetes as 62 Million in year 2014 [25]. The direct, indirect and intangible cost of diabetes is humongous and if appropriate actions are not taken there is a chance that the infrastructure available for the treatment of the disease will not be sufficient.

II. HEALTHCARE INFRASTRUCTURE IN INDIA

The healthcare -infrastructure indicator helps us understand the healthcare delivery provisions and mechanisms in India, and signify the investments and priority needed for creating the infrastructure in public and private sectors. The healthcare infrastructure in India is lagging far behind when we compare it with the WHO recommendations. India has 0.7 beds per thousand patients (for all diseases) which is very poor. The doctor-patient ratio (Doctors of all specialty, General Physicians & Family Medicine) in rural areas of India is 1:20,000, while the urban ratio is 1:2,000 against the statutory 1:250 ratio from WHO for which India requires 6,00,000 doctors[18]. If we consider 60% of India lives in rural areas, average number of doctors per thousands in India becomes 1:9200. The 31.7% villages still don't have primary healthcare centres in India [19].



Source: National Health Profile, 2008

Figure 1: Number of Beds per Thousand Patients (for all diseases)

Infrastructure/Services	% Villages
PHC	68.3
Sub-centre	43.2
Govt. Dispensary	67.9
Govt. Hospital	79.0
Private Clinic	62.7
Private Hospital	76.7

Source: RCHS Round II, 2004.

Figure 2: Rural Healthcare Infrastructure in India

III. CAPACITY PLANNING

Capacity planning is the efficient use of resources by projecting the healthcare needs. The process of capacity planning involves collecting a significant amount of data on how healthcare currently operates. It is one of the ways in which we prepare ourselves, to use that capacity data to make changes to the healthcare infrastructure to keep up with the demand.

Forecasting is a very important step in capacity planning. It is the response to the forecast that ensures the integrity of the healthcare processes. The steps used in Capacity planning are [20]:

1. Collect the Data and Identify the trend
2. Make projection against those trends
3. Develop a plan to mitigate the risk and ensure the integrity of the healthcare processes

Use of System Dynamics in Capacity Planning: System dynamics models as a forecasting tool can add value in four ways [21]:

1. System dynamics models can provide more reliable forecasts of short- to mid-term trends than statistical models, and thus lead to better decisions
2. System dynamics models provide a means of detecting changes in industry structure, as part of an early-warning-system or on-going learning system
3. System dynamics models provide a means of determining key sensitivities, and therefore of developing more carefully thought out and robust sensitivities and scenarios.
4. System dynamics models allow the determination of appropriate buffers and contingencies that balance risks against costs.

IV. OBJECTIVE OF THE RESEARCH

1. To find out the number of doctors required by the year 2025 to deal with diabetes in India
2. To find out the number of beds required by the year 2025 to deal with diabetes in India
3. To estimate the number of deaths due to diabetes by the year 2025

V. METHODOLOGY

The System Dynamics model was used to estimate the number of beds and doctors required to deal with diabetes in India in year 2025.

We developed the SD diabetes model using well-established techniques for model formulation and testing. The literature published on diabetes and healthcare were reviewed to estimate the parameters used in the model. We were able to draw parameter estimates directly from the available information in literature. The software used for SD Modeling was Vensim.

The SD diabetes model specifies how normal population converted into a population inflicted with diabetes. The figure below depicts a simple model for estimation of Doctors and Beds required for effectively tackling the challenges posed by diabetes in India.

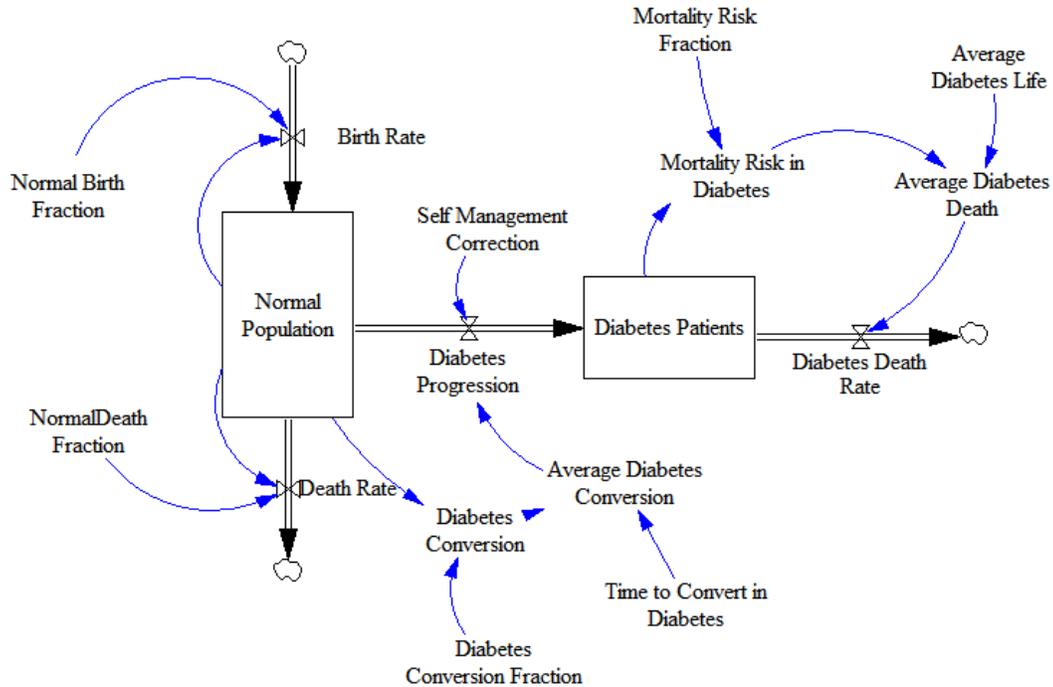


Figure 3: SD Model for Diabetes for Estimation of Infrastructure Demand

Following is a summary of the elements of Figure 2 used in Diabetes SD Model:

1. Normal Population: 1.236 Billion (Estimation in July 2014) [24]
2. Normal Birth Fraction: 1.25% [23]
3. Normal Death Fraction: 8 per thousand [22]
4. Diabetes Conversion Fraction: 0.028 [28]
5. Mortality Risk Fraction: 0.029 [26]
6. Patient Doctor Ratio: 250 [18]
7. Patient Bed Ratio: 1000 (assumed)
8. Diabetes Patients: 62 Million [25]
9. Time to convert into diabetes: 5 (assumed)
10. Average Diabetes Life: 10 (assumed)

Calculation of Diabetes Conversion Factor:

Taking Rural IGT: 7.9, Urban IGT: 8.7 and assuming 2:3 as urban to rural weight the average IGT was found 8.22 [28]. Considering 35% IGT suffer from Diabetes, the conversion factor becomes 2.8%.

VI. DIABETES SYSTEM DYNAMICS MODEL

- (01) Average Diabetes Conversion = SMOOTH (Diabetes Conversion, Time to Convert in Diabetes) Units: thousands
- (02) Average Diabetes Death = SMOOTH (Mortality Risk in Diabetes, Average Diabetes Life) Units: thousands
- (03) Average Diabetes Life = 10 Units: Years
- (04) Birth Rate = Normal Population * Normal Birth Fraction Units: thousands
- (05) Death Rate = Normal Death Fraction * Normal Population Units: thousands
- (06) Diabetes Conversion = Normal Population * Diabetes Conversion Fraction Units: thousands
- (07) Diabetes Conversion Fraction = 0.028

- (8) Diabetes Death Rate=Average Diabetes Death Units: thousands
- (9) Diabetes Patients= INTEG (Diabetes Progression-Diabetes Death Rate, 62000)
Units: thousands
- (10)Diabetes Progression=DELAY3 (Average Diabetes Conversion*Self Management Correction, 5) Units:
thousands
- (11)FINAL TIME = 100 Units: Years
The final time for the simulation.
- (12)INITIAL TIME = 0 Units: Years
The initial time for the simulation.
- (13)Mortality Risk Fraction=0.024
- (14)Mortality Risk in Diabetes=Diabetes Patients*Mortality Risk Fraction Units: thousands
- (15) Normal Birth Fraction=0.0125
- (16)Normal Population= INTEG (Birth Rate-Death Rate-Diabetes Progression, 1.236 Billions) Units=thousands
- (17) Normal Death Fraction=0.008
- (18)SAVEPER =TIME STEP Units: Years
The frequency with which output is stored.
- (19)Self Management Correction=0.2
- (20) TIME STEP = 1
Units: Years
The time step for the simulation.
- (21)Time to Convert in Diabetes=5
Units: Years

VII. RESULTS & DISCUSSIONS

The simulation of the System Dynamics Model provides the results which can help us in planning the infrastructural needs to address the healthcare demand due to diabetes. The table only lists first ten years result out of hundred time periods.

Table 2: Results of the Simulation Run

Time (Years)	Diabetes Patients (thousands)	Diabetic Deaths (thousands)
0	62000	1798
1	129418	1798
2	196836	1993.51
3	264059	2364.99
4	330910	2894.26
5	397231	3564.47
6	462880	4359.99
7	527722	5266.34
8	591640	6270.1
9	654528	7358.85
10	716290	8521.1

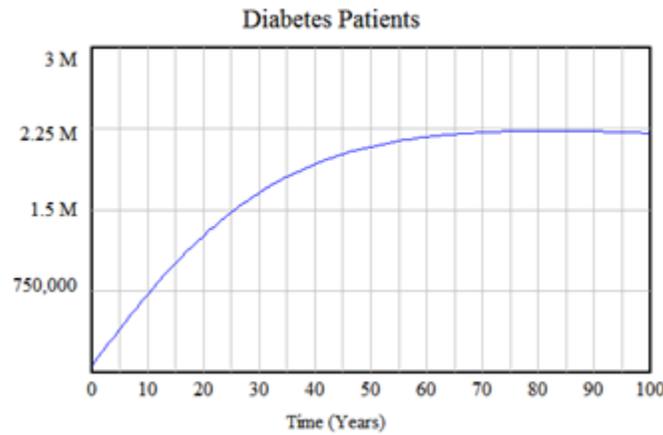


Figure 4: Graph for the Estimation of the Number of Diabetic Patients

The number of diabetic patients first increases and then becomes saturated around hundred years.

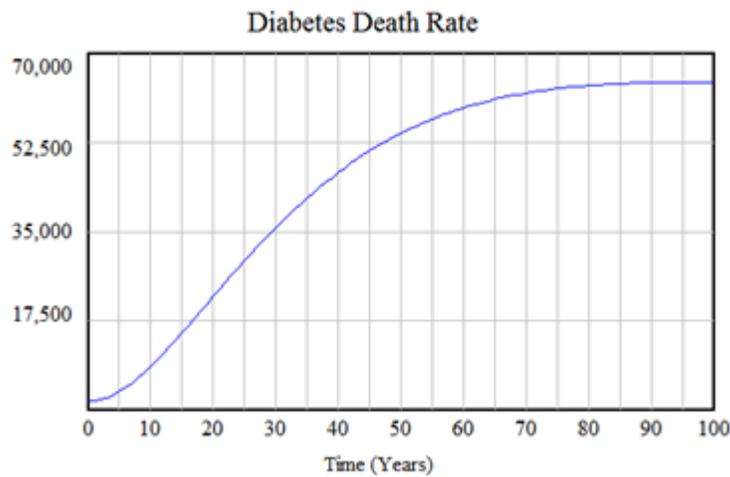


Figure 5: Graph for Estimation of Number of Deaths

The number of deaths due to diabetes like the number of diabetic patients, first increases then saturates. This is because we have used Self Management Correction factor (0.2) in the SD model used. In absence of this correction factor, the number would have increased more readily and then decreased like the typical epidemic curve [27].

Table 3: Estimation of Results in Year 2025

Diabetes Population(2025)	Bed Required	Doctors (250:1 Ratio)
716 Millions	0.72 Millions	2.86 Millions

According to the study, the diabetic population is expected to become 716 Million by considering IGT figure of 7.9 % for rural and IGT figure of 8.7 % for Urban Population. According to the World Bank Indicator data, India has an availability of 0.7 beds and one doctor per 9.2 thousand patients. Indian population is expected to become 1393 Million by 2025[8]. If India remains at the same level in infrastructure availability, the country will have 0.975 Million Beds and 0.015 millions doctors for all the diseases, while the requirement of beds and doctors is 0.72 Million and 2.86 Million respectively. The number of deaths due to diabetes is projected to reach 8.5 Million, which is a huge number in itself.

Indian government needs to open up more medical colleges, and encourage the private sector to enter the medical education sector, so that more and more number of healthcare professionals including doctor can be produced. The role of self help group is very important in promoting self management in diabetes and Non Government Organizations (NGO) can play an important role here. The government should allocate a higher percentage of GDP (present spend is around 5%) on building the healthcare infrastructure. The present out of the pocket spending on medical care is 75%, which needs to be brought down, by creating awareness about medical insurance. Considering the mortality in diabetes and the related complications, the medicines and hospitalization facilities in diabetes should be made affordable to a larger population.

VIII. LIMITATIONS OF THE STUDY

The data used for building the system dynamics model is taken from secondary sources and their claim is not consistent. Inclusion of more variables in the model will help us in understanding the diabetes management better.

IX. FUTURE DIRECTIONS OF THE STUDY

The future study may include the variables causing diabetes, and its progression in place of diabetes- conversion ratio. The future study should use data from primary sources. The study can also include the economic burden of diabetes in system dynamics model

ACKNOWLEDGEMENT

This research was supported/partially supported by Indian Institute of Technology (IIT) -BHU, Varanasi. We are thankful to our colleagues at IIT-BHU, who provided expertise that greatly assisted in the research.

REFERENCES

- [1] General Diabetes Facts and Information. (2015, September 14). Retrieved from Joslin Diabetes Centre: http://www.joslin.org/info/general_diabetes_facts_and_information.html
- [2] IDF. (2015, September 20). Retrieved from Complications of Diabetes.
- [3] Satyavani Kumpatla, Hemalatha Kothandan, Shabana Tharkar, Vijay Viswanathan, The Costs of Treating Long Term Diabetic Complications in a Developing Country: A Study from India, JAPI February 2013 ,VOL. 61,p 102-109
- [4] Rogowsky J, Lillard LA, Kington R: The financial burden of prescription drug use among elderly persons. *Gerontologist* 37: 475–482, 1997
- [5] Dubois RW, Chawla AL, Neslusan CA, and Smith MW, Wade S: Explaining drug spending trends: does perception match reality? *Health Aff (Millwood)* 19: 231–239, 2000
- [6] Karter AJ, Stevens MR, Herman WH, Ettner S, Marrero DG, Safford MM, Engelgau MM, Curb JD, Brown AF, the Translating Research Into Action for Diabetes Study Group: Out-of-pocket costs and diabetes preventive services: the Translating Research into Action for Diabetes (TRIAD) Study. *Diabetes Care* 26:2294–2299, 2003
- [7] Piette JD, Heisler M, Wagner TH: Problems paying out-of-pocket medication costs among older adults with diabetes. *Diabetes Care* 27: 384–391, 2004
- [8] Census of India, Retrieved on September 12, 2015 from India Stat, www.indiastat.com
- [9] Ministry of Home Affairs, Government of India, Retrieved on September 12, 2015 from India Stat, www.indiastat.com
- [10] Mohan V, Shanthirani CS, Deepa M, Deepa R, Unnikrishnan RI, Datta M. Mortality rates due to diabetes in a selected urban south Indian population—the Chennai Urban Population Study [CUPS—16]. *J Assoc Physicians India*. 2006 Feb; 54:113-7
- [11] Patel JC, Dhirawani M, Despande NM. Causes of deaths in diabetes mellitus. *Proc World Congress on Diabetes in Tropics*. 1996; 418-419
- [12] Das S, Mishra RK, Jena BB, Mishra BK, Misra KC, Sarangi B. Mortality events amongst non-insulin dependent diabetes mellitus patients in Orissa. *J Assos Physicians India* 1999; 47:1152-1156

- [13] Bhansali A, Chattopadhyay A, Dash RJ. Mortality in diabetes: a retrospective analysis from a tertiary care hospital in North India. *Diabetes Res Clin Pract.* 2003; 60:119-124
- [14] Singh RB, Bajaj S, Niaz MA, Rastogi SS, Moshiri M. Prevalence of type 2 diabetes mellitus and risk of hypertension and coronary artery disease in rural and urban population with low rates of obesity. *Int J Cardiol* 1998; 66:65-72
- [15] International Working Group on Diabetic Foot Report, International Diabetes Federation, Retrieved from IDF website, https://www.idf.org/webdata/docs/background_info_AFR.pdf
- [16] Dr. David Muiry, Mortality Associated with Diabetes, A review paper prepared for the 7th Global Conference of Actuaries, New Delhi, 15-16 February, 2005
- [17] V. Mohan, S. S. (2007). Epidemiology of type 2 diabetes: Indian scenario. *Indian J Med Res*, 217-230.
- [18] Indian Chamber of Commerce, Healthcare Infrastructure and Services Financing in India 15 September 2012
- [19] Laveesh Bhandari and Siddhartha Dutta, Health Infrastructure in Rural India, *India Infrastructure Report 2007*, 265-285
- [20] Trending, Forecasting, and Capacity Planning, *Pro Java EE 5 Performance Management and Optimization*, Springer, pp 317-335
- [21] Barnett, William. Four Steps to Forecast Total Market Demand. *Harvard Business Review*, July-August 1988, 28-37.
- [22] World Bank, (2015, September 15). World Bank. Retrieved September 15, 2015, from World Development Indicators: <http://data.worldbank.org/indicator/SP.DYN.CDRT.IN>
- [23] "Birth Rate, Death Rate, Infant Mortality Rate and Total Fertility Rate: India and States". National Commission on Population, Govt of India. 2010.
- [24] CIA World Fact book-India, Retrieved on September 10, 2015 from <https://www.cia.gov/library/publications/resources/the-world-factbook>
- [25] Shamima Akter , M Mizanur Rahman , Sarah Krull Abe & Papia Sultana, Prevalence of diabetes and prediabetes and their risk factors among Bangladeshi adults: a nationwide survey
- [26] V. Mohan, S. Sandeep, R. Deepa, B. Shah, C. Varghese, Epidemiology of type 2 diabetes: Indian scenario, *Indian J Med Res* 125, March 2007, pp 217-230
- [27] History of Epidemics and Plagues (October 2001)
- [28] Diabetes in India. Retrieved September 22, 2015, from www.diabetes.co.uk.
- [29] Diabetes Atlas, Third Edition, International Diabetes Federation, 2006

BIOGRAPHY

Vinaytosh Mishra is currently a Research Scholar in Department of Mechanical Engineering (IIT-BHU). He had done his B Tech from IIT (BHU) and MBA from IMNU- Ahmedabad. He has 8 years of experience with companies like IIL, India Today, India Mart and Religare. Recently he worked as the Vice- President Marketing at FIIT-JEE Edusoft limited. His area of interest includes Supply Chain Management, Decision Sciences, Data Analytics and Digital Marketing.

Dr. Cherian Samuel is presently working as an Assistant Professor in Department of Mechanical Engineering (IIT- BHU), Varanasi, UP, India. His education qualification includes B.Tech, M.Tech. & Ph.D. His area of interest is Supply Chain Management, System Dynamics, Production & Operations Management.

Prof. S. K. Sharma is presently the Institute Professor in Department of Mechanical Engineering (IIT-BHU), Varanasi, UP, India. He completed his B Tech and M Tech degree from Institute of Technology, BHU. His PhD is from Indian Institute of Technology, Kharagpur. His research area are Industrial & Manufacturing Engineering, Engineering Management, Simulation, System Dynamics, Supply Chain management, Operations Research, Production Planning and Control etc.